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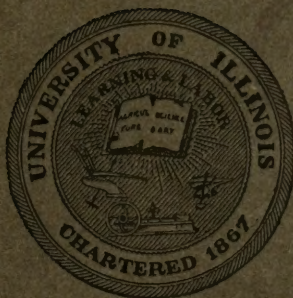
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THE STORAGE OF BITUMENOUS COAL

BY

H. H. STOEK



CIRCULAR No. 6

ENGINEERING EXPERIMENT STATION

PUBLISHED BY THE UNIVERSITY OF ILLINOIS, URBANA

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UNIVERSITY OF ILLINOIS
ENGINEERING EXPERIMENT STATION

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H. H. STOEK

PROFESSOR OF MINING ENGINEERING

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THE STORAGE OF BITUMINOUS COAL

I. INTRODUCTION

1. *Preliminary Statement.*—The coal shortage during the winter of 1917-18, and the resulting inconvenience, suffering, and industrial loss have emphasized both the importance and the complexity of the problem of guarding against a recurrence of the situation. The problem is one which concerns not only the Federal Fuel Administration and the State Councils of Defense, but the individual industry and even the individual household. It is generally recognized that perhaps the most important factor contributing to the shortage of fuel has been the inability of the transportation system to handle the heavy winter fuel tonnage in addition to the abnormally large tonnage from other sources. It is evident, therefore, that if large quantities of coal can be stored at or near the point of use during those seasons when consumption is lightest and when the railroads are best able to handle the traffic, an important step will have been taken in the solution of the problem.

It is the purpose of this circular to present a review of modern practice governing the storage of coal and a statement of the facts which have developed in the experience of those who have successfully or otherwise undertaken to store coal. The discussion is confined largely to bituminous coal which has given so much trouble owing to its tendency toward spontaneous combustion while stored, and to storage systems and mechanical devices.

The storage of coal should be regarded not merely as a war measure, but as part of the solution of the general coal problem. Storage of coal will do much to help in stabilizing an industry of fundamental importance by permitting mining operations to proceed throughout the year at a fairly uniform rate, and it will serve in a large measure as insurance against the losses accompanying a shortage to the fuel consuming industries.

At the present time large quantities of coal are stored by distributing companies on the Great Lakes and along the seaboard; fairly large quantities by coke, steel, gas, and power plants, by a

few wholesalers situated at a distance from the coal fields, and by many railroads; smaller quantities by small power plants and a few mining companies; and still smaller quantities by the ordinary householder.

Interest in the subject of coal storage is rapidly increasing, a fact which is shown by the large number of letters received by the Department of Mining Engineering and the Engineering Experiment Station of the University of Illinois, and the amount of coal stored will no doubt increase as the feasibility and advantages of storage become more fully understood.

The data presented have been compiled from the record of correspondence and interviews with a large number of persons in charge of storage yards, with the manufacturers of storage machinery, and with the officials of various coal associations. Visits have been made to a number of plants in Illinois and the adjoining states, and the literature of the subject has been freely consulted. It has thus been possible to compile within a comparatively short period the results of the experience of those who have been storing coal. In order to reach as many different sources of information as possible a questionnaire was prepared and sent to about 175 individuals and corporations.* Groups of industries were selected in order that as many different points of view as possible might be presented. These groups included the zinc smelting companies in Illinois, the steel companies and the by-product coke companies of Illinois, Indiana, Wisconsin, and Missouri, large public service corporations, many of the steam and electric railroads, representative wholesale and retail dealers suggested by I. L. Runyan, Secretary of the Illinois and Wisconsin Coal Dealers Association, the secretaries of all the coal operators' associations in the United States, the dock owners about the Great Lakes, large manufacturers, and other users of coal. The fire departments of a large number of cities were also consulted. The careful and prompt attention given to the requests for information indicated a wide-spread interest in the subject, and the responses were most gratifying.

The theoretical considerations connected with the spontaneous combustion of coal and the other phenomena incident to coal storage have been investigated by S. W. Parr, H. C. Porter, F. K. Ovitz, and J. B. Porter, and the results of much experimental work by these and

* The form of this questionnaire is shown on p. 130.

other investigators are contained in the publications of the Engineering Experiment Station of the University of Illinois, the U. S. Bureau of Mines, and the Canadian Department of Mines. There is presented here only such a summary of these results as is necessary for a consideration of the engineering features of coal storage.

The International Railway Fuel Association as the result of a paper on coal storage by its former secretary, C. G. Hall,* has carried on a most valuable work through its Committees on Coal Storage and Fuel Stations. The Committee on Prime Movers of the National Electric Light Association also presented a useful report,† in 1917, on the subject of coal storage.

This circular represents merely a report of progress in an investigation which it is hoped will be continued. Its purpose is to bring to the attention of those who are considering the advisability and possibility of insuring themselves a regular fuel supply as much in the way of useful and helpful suggestions as possible. Additional data or suggestions from those into whose hands the circular may fall will be welcomed by the author.

2. *Acknowledgments.*—Grateful acknowledgment is made of help accorded by PROFESSOR S. W. PARR, Professor of Applied Chemistry, University of Illinois, and PROFESSOR E. A. HOLBROOK, Supervising Mining Engineer, Metallurgist and Superintendent of U. S. Bureau of Mines, Urbana, Illinois, and formerly Professor of Mineral Preparation and Utilization at the University of Illinois, who have coöperated most heartily and have contributed data gathered in connection with their own investigations of the subject.

Wherever it has been possible, full credit has been given for definite data used and for direct quotations from other publications, but it has been impossible to do so in all cases, and many of the opinions expressed and the suggestions made represent composite ideas based upon a large amount of correspondence and much reading.

3. *Summary of Conclusions.*—Based upon the facts and information hereinafter presented certain definite statements are justified regarding the reasons for storing coal, the kinds and sizes of coal to be stored, the methods of piling, and other factors entering into

* "Storage of Coal: Its Feasibility and Advantages to Producer, Carrier and Consumer," Proceedings, International Railway Fuel Association, Vol. VI, pp. 109-130, 1914.

† Published by the National Electric Light Association, New York City.

the problem of successful coal storage. These represent very largely a digest of opinions expressed by many persons who have had experience in storing coal and, it is believed, constitute a comprehensive statement of the present knowledge of safe coal storage practice. These conclusions are presented as follows:

(1) It is practical and advantageous to store coal not only during war times but also under normal conditions, at the mine, near the point at which it is to be used, or at some intermediate point. If possible, it should be stored near the point of consumption to avoid rehandling and the resultant breakage.

The reasons for storing coal are:

- (a) To insure the fuel consumer a supply of coal at all times.
- (b) To take advantage of low freight rates, or of low prices for coal at certain seasons of the year.
- (c) To permit the railroads to utilize their cars and equipment to the best advantage.
- (d) To maintain a uniform rate of production at the mines.

(2) Kinds and sizes of coal which may be safely stored:

(a) Although it is undoubtedly true that some coals may be stored with greater safety than others, the danger from spontaneous combustion is due more to improper preparation and piling of coal than to the kind of coal stored.

(b) Most varieties of bituminous coal may be safely stored if of proper size and if free from fine coal and dust. The coal must be handled in such manner as to prevent excessive breakage and the consequent production of much fine coal and dust when being placed in storage, because spontaneous combustion is due mainly to the oxidation of the coal surface. The danger of spontaneous combustion in storing coal is very greatly reduced, if not entirely eliminated, by storing only lump coal from which the dust and fine coal have been removed. Of two coals, the one which is least friable should be chosen for storage purposes because less dust and fine coal will be produced in its handling. All varieties of bituminous coal can be stored under water, since water excludes the air and prevents spontaneous combustion.

(c) Fine coal or slack has sometimes been safely stored in cases in which air has been excluded from the interior of the

pile. Exclusion of air from the interior may be accomplished (1) by a closely sealed wall built around the pile or (2) by close packing of the fine coal. Any pile of slack requires careful watching to detect evidences of heating and means should be provided for moving the coal promptly if heat develops. The only absolutely safe way to store slack or fine coal is under water.

(d) Many varieties of mine run coal cannot be stored safely because of the presence of fine coal and dust mixed with the lumps.

(e) Coal exposed to the air for some time may become "seasoned" and thus may be less liable to spontaneous combustion because of the oxidation of the surfaces of the lumps of coal, but opinions are by no means unanimous on this point.

(f) It is believed by many that damp coal or coal stored on a damp base is peculiarly liable to spontaneous combustion, but the evidence on this point is by no means conclusive. It is safer not to dampen the coal when or after it is placed in storage.

(3) The effect of sulphur on spontaneous combustion:

It has been shown by experimentation that the sulphur contained in coal in the form of pyrites is not the chief source of spontaneous combustion, as was formerly supposed, but the oxidation of the sulphur in the coal may assist in breaking up the lumps of coal and thus may increase the amount of fine coal which is particularly liable to rapid oxidation. Ever this opinion is not unanimously endorsed. In spite of experimental data showing that sulphur is not the determining element in spontaneous combustion, the opinion is wide-spread that, if possible, it is well for storage purposes to choose a coal with a low sulphur content.

(4) Method of piling coal:

(a) To prevent spontaneous combustion, coal should be so piled that air may circulate freely through it and thus may carry off the heat due to oxidation of the carbon, or it should be so closely packed that air cannot enter the pile and oxidize the fine coal.

(b) Stratification or segregation of fine and lump coal should be avoided, since an open stratum of coarse lumps of coal provides a passage through which air may enter and come in

contact with the fine coal, thus oxidizing it and starting combustion.

(c) If space permits, low piles are preferable since in low piles the coal is more fully exposed to the air and is better cooled than in high piles and in case of heating it can be more readily and quickly moved. A disadvantage of high piles lies in the greater difficulty of moving the coal quickly, if necessary. The idea that a high pile causes heating at the bottom is erroneous, since as many fires take place near the top as near the bottom, and as many near the outside as near the interior of the pile. If possible, the coal should be divided by alleyways so as to facilitate rapid loading out of the coal in case of necessity, and so that an entire coal pile may not be endangered by a local fire.

(d) Much of the attempted ventilation of coal piles has been inadequately done through the use of only an occasional ventilation pipe, which has been not much more than a place in which to insert a thermometer. The practice of placing ventilating pipes closely together has been used in Canada and is reported to be effective.

(e) Water is an effective agent in quenching fire in a coal pile only if it can be applied in sufficient quantities to extinguish the fire and to cool the mass. A small quantity of water is not effective. Unless there is an ample supply of water thoroughly to quench the fire and to cool the pile, it is very dangerous to add any water to a coal pile.

(f) Coals of different varieties should if possible not be mixed in storage, for the coal possessing the greatest tendency toward spontaneous combustion may jeopardize the safety of other varieties not so liable to spontaneous combustion.

(5) The effects of storage upon the properties of coal:

(a) The heating value of coal as expressed in B. t. u. is decreased very little by storage, but the opinion is wide-spread that storage coal burns less freely than fresh coal. Experiments indicate that much of this deficiency may be overcome by keeping a thinner bed on the grate and by regulating the draft.

(b) The coking properties of most coals seem to decrease as a result of storage, but coals vary greatly in this respect.

(c) The deterioration of coal stored under water is negligible, and such coal absorbs very little extra moisture. If only part of a coal pile is submerged, the part exposed to the air is still liable to spontaneous combustion.

(6) Additional precautions :

(a) The best preventive of loss in coal storage is regularly to inspect the pile. If the temperature reaches 150 degrees F., the pile should be carefully watched and if the temperature rises to 175 or 180 degrees F. the coal should be removed as promptly as possible. The coal should be thoroughly cooled before being replaced in storage.

(b) Storage appliances and arrangements should be so designed as to make it possible to remove the coal quickly if necessary, and coal should not be stored in large piles unless provision is made for loading it out quickly.

(c) Pieces of wood, greasy waste, or other easily combustible material mixed in a coal pile may form a starting point for a fire, and every effort should be made to keep such material from the coal as it is being placed in storage.

(d) It is important that coal in storage should not be subjected to such external sources of heat as steam pipes, because the susceptibility of coal to spontaneous combustion increases rapidly as the temperature rises.

Warning: Special emphasis is laid upon the fact that safety in the storage of coal depends upon a very careful and thorough consideration of and attention to the details referred to in the foregoing. Lack of attention to these details and lack of care in handling will in many cases result in losses due to dangerous fires. Do not undertake to store coal until you are sure you know how to do it properly and safely.

II. REASONS FOR STORING COAL

4. *Present Mining Conditions.*—An ideal condition with regard to the production, distribution, and utilization of coal would permit the steady operation of mines without requiring the storage of large quantities of coal. There would be just enough mines to produce the coal required with only a suitable excess as a safety factor; these mines would be operated steadily for from 300 to 310 days per year and the coal would be taken away as rapidly as produced and delivered to the consumers as needed. This ideal condition is, however, far from being fulfilled. The actual condition is that an excessive number of mines is being operated, variously estimated as capable of producing from 50 to 150 per cent above the normal demands of the market, that these mines are irregularly worked for a total of only about 200 days per year producing much less during the spring and summer than during the fall and winter, and that the railroads have not adequate equipment to handle all the coal if all the mines were operated full time.

The storage of coal will not increase the amount used, and it may result in closing down unprofitable mines and in discouraging the opening of new mines until the readjusted demand may justify the operation of such mines on a profitable basis. Storage should make possible fairly uniform operation throughout the year and should help make the coal industry stable instead of intermittent and uncertain as at present. More nearly uniform operation of the mines and a greater number of days of work per year are necessary if coal is to be produced at a minimum cost and if the miners are to be kept satisfied, for no body of workmen can be satisfied with the irregular working conditions which have prevailed for many years in the coal mines of the United States. Regular operation also means the more systematic removal of the coal, greater extraction, and greater conservation of a natural resource.

The variation in the price of screenings has frequently been very great. In the summer, when the demand for coal has been small and the demand for fine sizes relatively large, screenings have commanded a price of one dollar or more per ton, while in the fall and early winter, when the demand for coal is greatest, the production of screenings has sometimes been so much in excess of the immediate

demand as to reduce the price at the mine to as little as ten cents per ton.

The variations in prices for different sizes of coal, as given by Prof. E. A. Holbrook,* show the advisability, from the standpoint of the buyer, of stocking coal to secure the advantage of lower prices during certain seasons. The general or extensive storage of coal should equalize these widely varying prices.

5. *Benefits of Storage.*—The reports of the Coal Storage Committee of the International Railway Fuel Association have shown that transportation lines should store coal, first, to assure a continuous supply of fuel for railroad operation at times when the supply from the mines may be cut off by floods, storms, labor disturbances, or other causes, and secondly, to avoid the necessity of providing the excessive equipment of locomotives and coal cars which are needed if all the fuel demands of the winter season must be met during that season. This excessive equipment is a non-productive investment during a part of the year.

Hall† says:

“The storage of coal in the summer months will enable the carriers to move a percentage of the tonnage during that season, which they are now called upon to move during sixty to eighty days of each fall and early winter, and during which period no railroad in this country now has, or ever can afford to have sufficient power and cars to serve the mines and move the coal to accord with the demand. To do this, we will say five of the large coal moving roads of Illinois and Indiana would each have to buy fifty new locomotives and six thousand new coal cars:

A total of 250 locomotives at \$25,000.00	\$6,250,000
A total of 30,000 cars at 800.00	24,000,000
Total Investment of	\$30,250,000

the annual interest on which, at five per cent, would amount to \$1,512,500, and a greater percentage of such cars and power would be idle eight months of the year.

“This is only a small portion of the total investment that even this small group of railroads would have to make in order to handle the coal as the consumers now demand, as the expense of additional double and triple tracks and yard facilities would far exceed the cost of additional equipment and power. It is therefore very apparent that the carriers would have to spend so much money to provide 100 per cent service during the short abnormal offerings of coal that

* “Dry Preparation of Bituminous Coal at Illinois Mines.” Univ. of Ill. Eng. Exp. Sta., Bul. No. 88, 1916.

† Op. Cit., pp. 110-111.

a substantial increase in freight rates would be the inevitable result, which of course would mean an increase in the ultimate delivered cost of the coal. Thus the consumers would not only be called upon to pay the interest on an excessive amount of capital invested in mines but would also have to carry the burden of an excessive investment in equipment and facilities on the part of the carriers."

Between May 15 and July 15, 1914, the railroads had a surplus of 95,564 coal cars, representing an investment of \$105,120,400. This amount of money would provide extensive storage facilities which would probably have a much longer life, and which would cost less for maintenance and depreciation than the surplus of coal cars. In the case of the railroads, one of the greatest advantages of storage lies in the opportunity it affords for moving railroad coal, which is not a revenue producing element, at a time when revenue producing freight shipments are least. Railroads need storage to control traffic, and the coal operators need it to regulate production.

Storage assures the wholesale and retail distributors of coal a supply in times of failure of railroads and of mines to furnish the regular daily supply owing to strikes and transportation disturbances. It permits distributors to take advantage of low freight rates, particularly through the use of water transportation in the summer time, and possibly also of lower prices of coal at the mines during slack mining time.

Hall* reached the following conclusions regarding coal storage:

"The storage of bituminous coal can only be made feasible by the producer, carrier and consumer coöperating closely to carry on the work in a systematic and economical manner.

"One million dollars spent by producers for storage facilities will afford more relief to the coal industry than five millions spent in the development of new mines.

"One million dollars invested in storage facilities by railroads would go further toward relieving operating tangles and preventing car shortage than three million invested in cars and locomotives.

"The purchase of coal by the industrial and domestic consumers, during the dull periods, will result in a saving of a very high per cent on the investment."

The reasons for storing may be summarized as follows:

(1) To assure the consumer an adequate supply which protects him against strikes, other labor disturbances, and uncertain railroad deliveries.

* Op. Cit., p. 130.

(2) To take advantage of water transportation and low freight rates.

(3) To secure the advantages of low prices.

(4) To equalize the prices on the different sizes of coal.

(5) To avoid the maintenance by the railroads of equipment which is used for only part of the year.

(6) To maintain a uniform rate of production at the mines

III. PLACES OF STORAGE FOR DIFFERENT PURPOSES

6. *Storage Near the Point of Consumption.*—The place of storage should be near the point at which the coal is to be used, not only to assure a constant supply to the user, but to avoid the extra cost and extra breakage incident to each rehandling and to utilize transportation equipment to the best advantage.

Hall* says:

“While unquestionably the best and most economical results can be obtained by moving the coal to final destination before storing, however, it may be desirable and necessary to establish storage yards at principal distributing centers such as Chicago, Peoria, St. Paul, and Omaha, and in doing this the coöperation of producers and carriers will be essential. In fact, it would probably be feasible and desirable for the producers to control the storage companies.

“These central storage yards should have a capacity of 100,000 to 500,000 tons, a screening plant to be installed in conjunction with the yard.”

7. *Storage for Domestic Use and for Small Power Plants.*—The domestic consumer does not always realize that if his winter supply of coal is delivered in October or November, when he begins to use it, or in small amounts throughout the winter, he is contributing to the car shortage and is helping to make necessary the maintenance of more mines than the actual yearly consumption will justify. The householder should realize that there is no other item in his living expenses which will pay as large a return on the investment as to lay in a supply of coal in May or June, when it may usually be procured from fifty cents to one dollar per ton cheaper than in October or November.

Although an increase in domestic storage during the summer is one of the simplest ways of helping to solve the storage problem, many householders cannot afford to pay their annual coal bill in a lump sum. Knowing this, retailers often ask on the basis of deferred or monthly payments as much as twenty-five cents a ton more than the cash price. The plan of making a definite reduction in price in the spring might be more generally tried. In the anthracite region of Pennsylvania, for instance, a reduction of fifty cents per ton in the retail price is usually made April 1 and an increase of ten cents per month is added until by September 1 this reduction has been

* Op. Cit., p. 113.

made up. Some such stimulus is justifiable to help keep the mines operating more steadily during the summer months and to allow the railroads to transport the coal when the car supply is available. Systematic advertising campaigns calling attention to the advantages of buying during the summer have been carried on by a number of coal dealers, notably in Springfield, Illinois, where full page advertisements have appeared in the daily and Sunday papers.

In small cities like Urbana and Champaign where the population is from 25,000 to 30,000 the amount of coal used per year is from 75,000 to 100,000 tons. The dealers estimate that an ordinary eight room house requires from fifteen to twenty tons per year, and that seventy per cent of this amount are stored in basements during the summer months, when the price is about fifty cents per ton less than in winter. In towns which have a large industrial population the percentage stored during the summer is less and the sales are distributed throughout the year. In towns where the local supply comes from neighboring mines, the incentive for storage is not so great since there is not often any variation in price and no likelihood of a scarcity.

Hall* says:

“If consumers are asked to coöperate with producers and carriers to the extent of storing some coal during the spring or summer they will expect to be shown wherein they will be benefited, and this also holds true in the case of dealers or jobbers who may plan to go into the storage proposition on a large scale.

“The producer has in the past, and will in the future unquestionably make sufficient price concessions during the spring and summer months to cause that to be an attractive feature of storage.

“The carriers should also offer inducements in the nature of freight rates with ‘storage in transit’ privileges and should make lower rates during the months that is to the advantages of all interests to store coal.

“The total operating expenses of the railroads moving the Illinois and Indiana coal to Chicago and the adjacent territory north and west show an increase of 31 per cent in proportion to gross earnings in a severe winter month as compared with a spring or summer month. It is therefore entirely fair, and in fact a sound business proposition for these carriers to make a corresponding variation in freight rates. For example the present rate to a given point is \$1.00 per ton—why should not a rate of 85 cents be made for the months of April, May, and June; 95 cents for July, August and September, and \$1.10 for the remaining months of the year?”

In this connection Coal Tariff 2338 of the Illinois Central Railroad, issued December 6, 1915, is of interest:

* Op. Cit., pp. 112-113.

"Storage in transit at Kankakee, Ill., of Bituminous Coal, C. L.

"Bituminous Coal, carloads, originating at Mines and Stations on Illinois Central Railroad and connections in Illinois, and destined to Chicago, Illinois, may be unloaded and stored in transit at Kankakee, Illinois.

"Shipments will be way-billed to Chicago, Ill., with notation on way-bill 'To be unloaded and stored at Kankakee, Ill.'

"The through rate, lawfully on file with the Illinois Public Utilities Commission, in effect on the date of forwarding from original point of shipment to Chicago, Ill., plus \$2.00 per car for reconsigning and extra service, will be protected when shipments are reloaded and forwarded to Chicago, Ill.

"On reshipments of storage coal the deduction for moisture, on shipments of screenings, from the actual net weight as ascertained on track scales at Kankakee, Ill., will be five (5) per cent.

"Agent at Kankakee, Ill., to show gross, tare and net weight, and deduction for moisture on face of way-bill.

"No deduction will be allowed if weighed en route or at destination.

"If the shipments are not forwarded from Kankakee, Ill., within six months from the date they were forwarded from original point of shipments, through rate, lawfully on file with the Illinois Public Utilities Commission, in effect from the original point of shipment to Chicago, Ill., will be collected at that time.

"Owners will be required to unload and reload the coal.

"Shipments will be subject to Car Demurrage Rules lawfully on file with the Illinois Public Utilities Commission.

"Note:—Applicable only on traffic having point of origin, destination and entire transportation within the State of Illinois."

In this connection, it is interesting to note the distribution among different classes of service of coal used in the city of Chicago.* A

TABLE 1
QUANTITY OF COAL AND COKE USED IN CHICAGO DURING 1912

SERVICE	TONS	PER CENT
(1) Steam Locomotives	2,815,400	13.27
(2) Steam Vessels	92,368	0.44
(3) High Pressure Steam Stationary Power and Heating Plants: Including public service corporations, municipal, steam railroads, office buildings, hotels, schools, power plants, or boiler plants . . .	9,147,344	43.13
(4) Low Pressure Steam and Other Stationary Heating Plants: Including large and small buildings, large and small apartments and residences	4,646,910	21.91
(5) Gas and Coke Plants: Excluding boiler power plants	253,867	1.20
(6) Furnaces for Metallurgical, Manufacturing and Other Processes: Including steel plants, foundries, forges and allied processes; brick, pottery and allied processes, and miscellaneous manu- facturing, rendering and other processes, excluding boiler power plants	4,253,007	20.05
Totals	21,208,886	100.00

* Report of the Chicago Association of Commerce Committee of Investigation on Smoke Abatement and Electrification of Railway Terminals, p. 110, 1915.

study of this table will indicate the points of attack in a campaign to increase the amounts of coal to be kept in storage.

The average retailer is in much the same condition as the householder, to the extent that he does business on limited capital and cannot afford to lay in a heavy stock, even if he has the required space and facilities. According to *The Black Diamond*,* there is one retail dealer in the United States for every two thousand inhabitants, which means that the average retailer handles only about 7500 tons per year. Since there is usually in every town some corporation which handles a large proportion of the retail coal business the average dealer's business will probably amount to much less than 7500 tons. There are at least twenty coal dealers in Champaign and Urbana for a population of about 25,000. Since the consumption in these towns is probably not over 100,000 tons per year, the average sales per dealer are not more than 5,000 tons. The ordinary retail dealer cannot afford to put much money into costly storage appliances which add greatly to his overhead charges, nor to buy the land necessary to store great quantities. The comparatively small amounts stored are kept usually in small bins under cover and are stored for only a short time.

One way out of the difficulty would be to establish coöperative storage plants which could serve as common storage facilities for a number of dealers. Such coöperative schemes have not, however, been generally successful. In Rock Island, Illinois, a company has built a number of storage bins which are rented. In a large city, storage facilities for any considerable quantity of coal would usually have to be located in the outlying districts to keep the rental cost for the land within reasonable limits. A ton of coal occupies about forty cubic feet; hence to store one thousand tons in a pile ten feet high would require a space sixty-three feet square.

Large office buildings, hotels, and stores are the largest users of coal per foot of floor area. In Chicago the amount used per building, according to *The Black Diamond*, varies from seven to sixty tons per day.

For large buildings two kinds of storage must be provided, namely, the current daily working storage and the reserve or emergency storage to tide over strikes, bad weather conditions, transportation difficulties, and other contingencies. Provision for the

* February 3, 1917.

storing of coal for the current supply is a necessity and need scarcely be considered in connection with the broader phases of the question, since it is a matter of architectural design and depends largely upon the space available in a given building. If a building requires 40 tons per day, a storage space of 1600 cubic feet is necessary for a day's supply and a room approximately 30 by 30 by 10 feet for a week's supply. According to *The Black Diamond*,* this storage space in the loop district of Chicago is worth a rental of three dollars per square foot per annum for power purposes. The Continental and Commercial National Bank uses this space for its vaults, and their rental value is about eight dollars per square foot. That makes its value two and two-thirds times the value of the same space for power generating purposes. The Rector building in Chicago rents its basement to a restaurant for six dollars per square foot. This fact shows that the basement is worth almost as much as the ground floor space, and more than twice as much as the office space of the upper stories. Such buildings must have a regular daily supply, and they must use their own space at a high rental loss, or some provision for storage must be made by the wholesalers, or by the railroads. Local storage of large quantities of coal for such a district as the loop in Chicago is, therefore, impracticable without an unreasonable increase in the fuel bill, and some other solution of this part of the problem must be worked out.

Public utilities companies, owing to the constantly increasing governmental supervision which requires uninterrupted service, and the by-product coke companies, the steel companies, and other industries which must run continuously must necessarily regard storage as a matter of necessity, unless they are situated near the mines. Many of the zinc smelters in Illinois, although in mining towns, have ample storage facilities.

8. *Storage by Railroads.*—The railroads are interested in storage both because they are the largest users of coal and because they are interested in utilizing their coal carrying equipment to the best advantage.

According to the United States Geological Survey, the railroads of the United States used, in 1916, 136,000,000 tons of bituminous coal (27 per cent of the total production), 6,735,000 tons of anthra-

* Op. Cit.

cite (7.1 per cent of the production), and 22,950 tons of coke. The railroad consumption of bituminous coal in 1916 showed an increase of 14,000,000 tons, or 11.5 per cent over 1915. The quantity of bituminous coal used by the railroads in the eastern district increased from 56,500,000 to 62,700,000, or 11 per cent. The increase in the southern district was from 22,000,000 to 23,300,000 or 5.1 per cent, and in the western district, from 43,500,000 to 50,000,000, or 15 per cent.

There is a difference of opinion concerning the place at which a railroad should store coal. Some recommend storage at the using point, i. e., at each coaling station, while others suggest some central point from which a number of coaling stations may be supplied. Even though the cost of providing storage facilities at each coaling station may be prohibitive at present, many advise that in locating coaling stations consideration be given to the possibility of subsequently erecting storage facilities at such points. Some recommend a central storage plant for each division, so that each superintendent may be responsible for his own fuel supply. Others recommend only general terminal supply stations. The cost of installation and operation of one large plant must be compared with that of a number of smaller ones, and the item of additional breakage must also be considered.

9. *Storage at the Mine.*—There is a wide diversity of opinion concerning the advisability of storing at the mine, many claiming that it is not desirable, since it neither increases the output nor helps the transportation problem. It is as logical economically for the producer of coal to store coal at the mine as it is for the manufacturer of cement to store cement at his plant.

Storage near the point of consumption is, of course, the best method, but storage at the mine possesses such advantages as to warrant its consideration. Even a small storage pile at the mine may permit the mine to begin running in the morning when railroad cars have not been delivered and when ordinarily the mine would not start owing to the uncertainty of a car supply later in the day. It may also often tide over periods of the day when additional cars are needed. During the early part of the week the car supply is usually good, but it falls off during the latter part, and storage should help to increase the regularity of running.

Carl Scholz* says:

"Lump and egg coal should be stored at destination by railroads, industrial plants, and domestic users during the period from April to August. Screenings should be stored at mines by coal operators during the period from September to January."

By storing at the mine, the operators are fortified against fluctuations in demand. Occasionally an operator cannot increase his output rapidly owing to insufficient mine development; whereas if he has a stored supply upon which to draw, he may retain the business and at the same time proceed with the development until his capacity is increased to meet the extra demand. Suitable storage facilities at the mine will make possible more rapid working and better extraction. Storage will also help to equalize the difference in demand for different sizes, and will permit shipments to continue when the mine is shut down. Operating expenses at a mine, as with the railroads, are usually greatest in the winter and mining would, therefore, be more profitable if the mines could be worked steadily during the summer and spring months.

E. A. McAuliffe† has stated the advantages of storing as affecting labor conditions at the mine as follows:

"A shop man ordinarily receives some limited notice relative to short hours or reduction of force. Engine and trainmen have learned by experience that business falls off at certain seasons, but they know at the same time that they will be permitted to make a mileage at least reasonably commensurate with their domestic and their financial requirements; not so with the miner, with the fellow that digs the coal; he works to the extreme limit of his ability, or at least he has the opportunity to work to the limit of his ability, one week, when suddenly, without notice, due possibly to an unforeseen weather condition, business slumps and he gets one day or two days a week. In the meantime his operating expenses are running on just the same. I think that condition is very largely responsible for the unrest, for the dissatisfaction, that the mine worker labors under. That he does not take a greater interest in the affairs of his employer, in the permanency of his vocation, I think is very largely due to the fact that he does not know what he is going to earn next week. When night comes he can sum up what he earned today, but he does not know what tomorrow holds in store for him. There is no business on earth subject to the tremendous and violent fluctuations that the production of coal is subject to. Today we demand the maximum, or if possible, more than the maximum output of all the mines; tomorrow we are quite indifferent to whether the operator sells his product or otherwise. The storage of coal, and the movement from the mines to the stock piles during these temporary depressed periods is the only same solution of that problem."

* Proceedings, International Railway Fuel Association, Vol. VII, p. 267, 1915.

† Proceedings, International Railway Fuel Association, Vol. VI, p. 143, 1914.

The small number of working days at Illinois mines is shown by the following table, taken from the Illinois Coal Report.

TABLE 2
DAYS OF ACTIVE OPERATION OF MINES FOR SEVENTEEN YEARS

Year	All Mines	Shipping Mines
	Days	Days
1900	183	214
1901	174	204
1902	179	210
1903	192	222
1904	198	213
1905	174	198
1906	172	189
1907	184	209
1908	171	191
1909	168	189
1910	171	179
1911	165	169
1912	160	172
1913	170	179
1914	162	174
1915	158	172
1916	163	185

IV. COAL STORAGE PRACTICE

10. *Kinds and Sizes of Coal which may be Safely Stored.*—The opinion is current that the locality from which a coal comes determines its suitability for storage. One frequently hears such a remark as, "Eastern coals (meaning those from Pennsylvania and West Virginia) can be easily stored but Western coals (meaning those from Illinois and Indiana) cannot be since they are much more liable to spontaneous combustion."

This statement is too general to fit the facts, because scientific research and the experience of those storing coal have shown that while there are undoubtedly inherent differences in coals which affect their liability to spontaneous combustion and to degradation, these differences are of less importance than the size of the coal and the way in which it is stored. The answers to the questionnaire (Appendix II) indicate that almost any coal may be stored if it is properly piled, and that almost any coal improperly stored will heat and may fire.

The C. W. Hunt Company, of Staten Island, makes the following statement:

"Any coal of fair quality, both anthracite and bituminous, can be successfully stored for an indefinite length of time. There is a slight deterioration both chemical and physical, but this is not serious, provided the coal does not heat. Low grade bituminous coals are subject to heating and should not be stored above twenty feet in depth or for very long periods. Any storage of bituminous coal should be watched and if found to heat, should be moved."

The Coal Storage Committee of the International Railway Fuel Association says with reference to storage by roads using Ohio, Pennsylvania, and West Virginia coals:

"The consensus of opinion in regard to the coals which may be screened without excessive breakage seems to be that the coal best adapted for storage is the three-fourths inch to the one and one-fourth inch lump. In the case of very friable coals such a separation of sizes is not practicable, for which reason they should be stored as run of mine and the storage piles so made as to minimize the danger attendant upon storing the coal of mixed sizes."*

With reference to storage by the railways in the southeastern part of the United States the Committee says:

* Proceedings, International Railway Fuel Association, Vol. VII, p. 260, 1915.

“It is agreed that lump coal of a firm quality, in order to resist powdering, is the best. The Central of Georgia Railway has been very successful in storing slack with a large percentage of nut. From the operators’ viewpoint, run of mine should be stored, as it leaves nothing on their hands.” *

With reference to southwestern railways the Committee says:

“It is generally agreed that lump and nut coal with at least twenty-five per cent of slack removed is the best kind to store, that is, with the coals which will store without great danger of spontaneous combustion.

“All who have tried to store Texas and part of the Arkansas coal have found that it is a failure on account of the liability to spontaneous combustion.

“All other coals in the second territory—Oklahoma, Kansas, Missouri, and Northern Arkansas—can be stored and the loss in heating value and weight will be from two per cent to eight per cent.” †

With reference to the railroads using Indiana, Illinois and Iowa coals the Committee says:

“Lump and egg coal should be stored at destination by railroads, industrial plants and domestic users during months April to August. Screenings should be stored at mines by coal operators during period September to January.” ‡

W. L. Abbott, Chief Engineer of the Commonwealth Edison Company, Chicago, says:

“The experience of the Commonwealth Edison Company after storing large amounts of all varieties of coal and particularly Illinois coals for a number of years may be summarized as follows:

“Nearly any coal which has gone over a 1½-inch screen can be stored. Any size of coal with duff left in will heat.

“Pea coal over one-half inch through three-fourths inches has been in storage for more than a year without heating. Coal with screenings removed has been kept in storage eight years without firing.

“Heating usually occurs within three months after the coal has been stocked, and the tendency to heat decreases rapidly after that period.

“Coal in storage piles shows no measurable loss of heating power, although weathering reduces the lumps on the outside of the piles to slack.

“As insurance, cost of handling, etc., are the same for all grades of coal, regardless of heat value, it is more economical to store the better grades.”

These statements are endorsed by others in Chicago who store large quantities of coal.

* Ibid., p. 262.

† Ibid., p. 264.

‡ Ibid., p. 267.

Hall * says:

"On account of the cheaper prices which have prevailed on slack coal, the industrial concerns of the country have gradually been installing steam plants so equipped as to burn successfully that grade, resulting in a proportionately stronger demand for screenings, from April to August of each year, than any other size. This creates an ideal condition for storage as it enables the operator to supply the railroads, and other concerns that require it, sized coal such as nut and egg for current use and the large lumps for storage. There has been a surplus of egg as well as lump coal during the spring and summer and this grade can also be stored to good advantage. The six-inch lump coal when stored and reloaded should be rescreened if any part of it is to be offered to the householder. Lump or egg when stored by the ultimate consumer and at the point of consumption can be recovered without appreciable degradation.

"During the fall and early winter, conditions are reversed and screenings become the unsalable size. This is the period that screenings should be stored at the mines."

A. Bement† says: "It appeared that egg coal was the best size to put in storage and there has been an enormous tonnage of it stored in the open with complete success."

11. *When Coal should be Stored.*—To keep the mines running regularly and to relieve the congestion of the railroads, coal should be stored during the spring and summer. Coal which is moved to the storage point by water must be stored during the summer and early fall before the close of water navigation.

From the standpoint of heating of the coal it is preferable to store during the cool days of the fall or winter, but many prefer to store during July and August, because then the coal is drier. Others prefer to store in May and June, because then labor is more easily obtained and more can be accomplished than during the hot summer.

W. D. Langtry‡ suggests the advisability of cooling steel coal cars before they are loaded and says:

"One item which might prevent trouble in storing is the condition of railroad cars in the summer when coal is loaded therein at the mines. We found that steel cars, for instance, would absorb the heat, to a great extent, from the sun, and if the coal was loaded into these cars this heat would be transmitted to the coal, thus giving it a good start for spontaneous combustion to continue. Some coals are more or less damp when freshly mined, and this and the heat are very good factors in giving the coal a good start. If the cars could be cooled in some way, by sprinkling them with a hose, when it is known that the coal is going in storage it might help somewhat."

* Proceedings, International Railway Fuel Association, Vol. VI, p. 125, 1914.

† The Black Diamond, April 7, 1917.

‡ Personal Communication.

The following statement by F. W. Gray* is of interest with relation to the effects of the temperature at which coal is placed in storage:

"The most extensive storage yet undertaken was in the winter months of 1913-1914, when 650,000 tons of coal were 'banked' by the Dominion Coal Company at their Glace Bay mines. The coal is lifted in the summer by steam shovels, rescreened and shipped. There has never yet been an actual fire in the round coal banks, although the first coal banked out must remain in the center of the pile for over six months before it is lifted. Heating sometimes takes place, but with proper methods this can be speedily checked and dissipated. The temperature of the air at the actual time of banking is an important consideration, as generally speaking the banked coal seems to remain at about the temperature which it had when placed in the bank. The bulk of the coal placed on the ground is, of course, put there in cold or freezing weather. If a thermometer is lowered down a pipe into the interior of the bank it will usually register a temperature near to the freezing point, a fact that it is interesting to observe on a hot summer day, when the surface of the banked coal is quite warm to the hand. The coal is banked up to a height of from 40 to 46 feet, and over 300,000 tons have been stored in a continuous pile."

There is the greatest danger when coal is stored during the hot months, July and August, and the liability is greatly reduced if it is stored in May, June, September, or October.

12. *Storage Piles.*—Storage piles are usually in the form of truncated cones or pyramids, the size depending mainly upon the appliances used for storing and reclaiming and upon the space available.

The different sizes of coal are sometimes, if space permits, kept separate in storage, but often this plan is impracticable and the coal must be screened, if at all, as it is taken out of storage.

If piled on the ground, the space should be clean, level and free from water or moisture. Many large piles are placed upon a board or concrete foundation.

There is a wide diversity of opinion concerning the height of piles, and many think that piles should be not more than ten feet high. The opinion often expressed that the height of the pile is an important factor affecting the extent to which coal at the bottom of the pile may be crushed does not seem to be substantiated by the facts. Tests made in the Materials Testing Laboratory of the University of Illinois on Illinois coal showed a maximum crushing strength of 2090 pounds per

* "The Coal Fields and Coal Industry of Eastern Canada." Canada Department of Mines, Bul. 14, pp. 11-12, 1917.

square inch and a minimum of 1280 pounds. Similar tests on Connellsville coal showed a maximum strength of 3430 pounds per square inch and a minimum of 1310 pounds. Tests in England required 1.27 tons per square inch to start cracking and 1.52 tons to crush the coal.

Coal is seldom piled at present more than fifty feet high and at this height the pressure at the bottom of the pile would be only about fourteen pounds per square inch which is so small compared with the crushing strength as to be negligible. Any increase in fine material in high piles is probably due mainly to the handling of the coal, as, for example, dropping it from a considerable height or allowing it to roll down a long slope and thus produce breakage and abrasion. None of those who pile coal to a considerable height reports any crushing due to the height of the pile.

Coal has been successfully stored in piles varying in height from six to sixty feet and it has also frequently fired in very low piles. The depth is not so important as the manner in which the coal is placed in storage and the facilities available for quickly removing it in case of firing.

An examination of piles which have fired shows that the fires have started frequently near the top and sides and not at any great depth in the pile. A current of air in the pile too sluggish to carry off the heat, a piece of wood, or oily waste may furnish a starting place for fire. The theory has been advanced that the temperature of a current of air rising through a pile of coal in which oxidation is taking place receives sufficient heat from the oxidizing coal to increase the tendency to spontaneous combustion near the top.

One objection to high piles lies in the difficulty of testing for heating. Low piles are advantageous because they can be easily watched and tested for a rise in temperature, and if necessary the coal can be removed quickly.

In connection with experiments made on coal stored by the Canadian Pacific Railway near Montreal, Canada, Prof. J. B. Porter* says:

"It is interesting to note that the series of observations prove very clearly that the maximum heating was comparatively near the surface of the pile. As a matter of fact the hottest points were apparently not more than five or six feet from the surface, although the weather at the time was extremely severe. The common opinion of practical men in charge of coal storage is that fires usually

* "Weathering of Coal." An Investigation of the Coals of Canada, Extra Vol., p. 164, 1915.

occur close to the bottom, but in this case it is almost certain that had the pile been left unventilated it would have ignited within a week or two at a depth of not over six feet, and in certain other cases which the author has observed, fires in large piles have actually originated at this depth. The probable reason is that in a pile of great extent and depth, the coal in the lower portions is so heavily compressed and so isolated from supplies of fresh air that it does not receive sufficient oxygen. It must be confessed, however, that the persons responsible for coal storage are not willing to act upon this theory, which, if followed to a logical conclusion, would lead to the storage of coal in very deep piles on ground impermeable to air."

A pile should be divided by alleyways into small units so that all parts may be easily accessible, and thus the danger of a fire spreading may be minimized.

13. *Ventilation of Coal Piles.*—It is a generally accepted theory that if the air supply is entirely shut off from the coal, as with under-water storage, spontaneous combustion cannot occur. It is also agreed that if ample ventilation can be furnished to carry off the heat and keep down the temperature in a coal pile, spontaneous combustion will not occur. It is the intermediate condition which is dangerous, that is, a condition in which enough air is admitted to permit the coal to oxidize and heat and not enough to carry off the heat as rapidly as it is generated. For this reason lump coal may be safely stored, because there is good circulation through the pile. On the other hand, run of mine often cannot be safely stored, not only because of the presence of an excessive amount of fine coal which oxidizes readily, but because the openings between the lumps are filled to a considerable extent by the fine coal and the free circulation of air is prevented. Alternate stratification of coarse and fine coal, therefore, is undesirable, and air passages formed by the large lumps rolling to the bottom of a pile should be avoided. Such passages form a duct or flue for a sufficient amount of air to reach the fine material inside the pile to start oxidation.

The practicability of properly ventilating a coal pile has been disputed and while the consensus of opinion in the United States is against ventilation by pipes, it is probable that many of the opinions expressed are based upon unfavorable results secured through improperly installed and inadequate ventilation systems. Many so-called pipe ventilation systems have consisted merely of an occasional pipe into which a thermometer may be inserted for reading tempera-

tures. There are of record few adequate ventilation systems being installed in the United States, because such systems are expensive and interfere to some extent with the rapid handling of the coal; such systems are also considered dangerous.

It is also stated by many that closely packed coal is so poor a conductor of heat that fire may start close to a ventilating pipe, and that it is impossible adequately to ventilate a coal pile.

J. H. Hibben* cites an instance of apparently successful ventilation† which he describes as follows: "In southern Texas several years ago we stored a large amount of Oklahoma mine run coal at Smith-

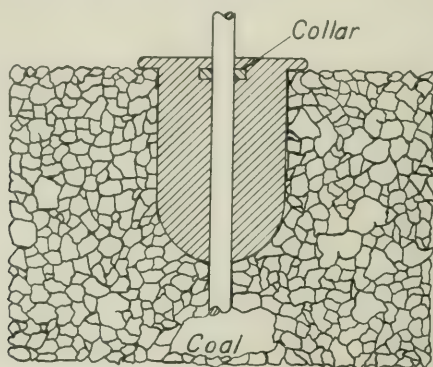


FIG. 1. METHOD OF VENTILATING COAL PILES EMPLOYED BY THE CANADIAN PACIFIC RAILWAY

ville, a coaling station near San Antonio. I experimented with one pile of coal by placing one six-inch glazed tile on the bottom for the entire length of the pile. This was the ordinary bell-shaped tile and it could be put together without cement, the ends butting against each other. In another adjoining pile an equal quantity of coal was stored without the use of tile and the result was that in the pile where the tiling had been placed, there was no fire, but in the other pile not tiled, there was a great deal of trouble with spontaneous combustion." Hibben says further: "I am of the opinion that pipes or flues do not always produce the desired results."

A comprehensive system of ventilation installed in Canada by the Canadian Pacific Railway is described by Porter‡ as follows:

* Op. Cit., pp. 152-153.

† Another instance of possible successful ventilation is referred to on page 150.

‡ Op. Cit., pp. 152-153.

“The method in general is: first to level off a triangular piece of ground so that temporary tracks may be laid upon it and a steam shovel used if desired. A track is then laid in and hopper-bottom coal cars unload on this track, which is then raised on the coal and the operation repeated until an embankment of considerable height is made, with an inclined track from the apex of the triangle to the main line. When a sufficient height is reached, the coal is side dumped or side shovelled and the track is gradually shifted to one side and the width of the pile thus increased to any desired extent. The height of the pile on the approach increases from nothing to about sixteen feet, and this latter height is maintained for the major portion of the pile.

“As soon as possible after each portion of the pile reaches its full height it is ventilated by driving pointed iron rods, $1\frac{1}{2}$ inches or 2 inches in diameter, vertically down through it. After the rod reaches the bottom a bell-shaped collar is slipped over it and forced down about six inches into the coal, as shown in Fig. 1. The rod is then tapped to compact the coal around it and to loosen the rod itself and both collar and rod are withdrawn. A rough funnel of tar paper is then put in the bell-shaped top of the hole to prevent pieces of coal falling in or being washed in by the rain. The walls of the lower part of the hole maintain themselves without protection, and holes driven in this way ordinarily last for many months. The distance between the holes varies somewhat with the circumstances; but generally it is about sixteen inches from center to center, and the cost, which is almost wholly labor, amounts to approximately five cents per ton.

“Another method, which is frequently effective, and in certain cases economically possible, is to pile the coal in layers of about two feet, allowing each layer to be exposed to the air for at least two days, and if possible much longer, before it is covered by the next layer. This method is usually effective in preventing fire, if the piling is done in cool weather, but in midsummer, particularly in hot and sunny weather, it is of doubtful value to say the least.”

This description is supplemented by Dr. Porter in a private communication, as follows:

“I have had personal experience of the storage in Montreal of very large quantities of coal from Nova Scotia and elsewhere, and of one case in England of the Storage of Welsh coal, where it has been found possible to ventilate the piles cheaply and effectively by air passage ways from the surface. To my personal knowledge these methods are still in successful use on a very large scale.

“In the majority of cases above referred to the ventilation was arranged at the time that the coal was stored, but in one or two cases under my own instruction ventilation was successfully applied to storage piles which had begun to heat, and in no single case under my observation was there any difficulty in cooling the coal; although in one instance at least the temperature had risen to 133 degrees F. and was going up with a constantly increasing rapidity.

“I am confident that the method can be successfully applied to the great majority of cases of storage. If the coal is known or suspected to be liable to heating, the ventilation holes should be driven at the time of piling and should

be inspected from time to time to see that they are kept open. If the coal is of a less dangerous character, or if for any reason ventilation cannot be provided at the start, it will suffice to make frequent observations of its temperature, and ventilate if serious heating begins.

"I may add that the method referred to is not of my own invention or discovery, but that circumstances made it possible for me to examine and test it very thoroughly on a very large scale with the result that I am firmly convinced that it is a perfectly practicable and reasonably inexpensive method for commercial storage on a very large scale.

"In spite of the numerous fires in coal piles in Canada during 1917, I am informed that not one single ventilated coal pile belonging to the Canadian Pacific Railway has caught fire either this year or for several years. The method of ventilation used by the C. P. R. and copied by various other concerns is set forth in detail in 'The Weathering of Coal,' pages 152-166; the only difference is that their present specifications are somewhat simpler as they find that one-inch holes suffice driven from twenty to twenty-four inches center to center in parallel rows. When I described the method the company ventilated its own piles, but now it does the work by contract in the majority of cases at a cost of about five cents per ton. The Canadian Pacific Railway Company stores from a million and a half to two million tons of coal each year; the main part of this coal being piled in the summer and used during the winter and spring; and the statement that they have no fires where they ventilate is therefore of very great weight. It is interesting to note that at a few C. P. R. storage points it was not found practicable to ventilate the piles this year, and Mr. Britt, the Fuel Agent of the Company, informs me that at these points heating has occurred and that at the most important of them (Fort William) they have had a very bad fire.

"Under ordinary conditions the main part of the Montreal coal supply comes from Nova Scotia in ships and is quite cold when it reaches here; in fact I have seen ice in the coal when it was being loaded in these ships at Sydney in mid-summer. This cool coal is ordinarily handled very quickly to the storage piles, and the piles themselves so laid out that as little as possible sun-heated coal is buried."

14. *Testing for Fires.*—The common methods of testing for the heating of a coal pile are:

(1) By watching to detect evidences of steaming in the pile.

(2) By noting the odor given off. The bituminous odor of burning coal or the odor of burning sulphur are evidences of heating.

(3) By inserting an iron rod into the pile and, when drawn out, noting its temperature by touching with the hand.

(4) By noting places where snow on a pile has melted.

(5) By means of maximum temperature thermometers inserted into pipes driven into the pile at intervals. These pipes

should have a conical plug in the bottom to facilitate driving them into the pile. After driving to the desired depth the plug may be withdrawn and the pipe raised a short distance from the bottom of the hole so that the actual temperature of the coal may be taken. The top of the pipe should be kept closed to reduce the effect of outside temperatures. Instead of leaving a pipe in the coal pile it is sometimes necessary only to drive it and then withdraw it, the hole remaining open sufficiently to permit the insertion of the thermometer. This method obviates one of the greatest objections to pipes placed in the pile; i. e., interference with the apparatus used for removing the coal. Self-registering thermometers protected by a metal casing may be bought from any dealer in scientific instruments. They may be had graduated according to the Fahrenheit or the Centigrade scale and adjusted to various ranges of temperature, the best range for this work being from 0 to 220 deg. F. The cost per instrument is about \$2.25 without armor and \$4.50 with armor.

In the experimental work carried on by Prof. J. B. Porter, of McGill University, a Richard thermograph was also used for recording temperatures.*

15. *Handling Fires.*—Opinions differ widely concerning the critical or dangerous temperature in a coal pile. Parr† says, "Bituminous coal can be stocked without appreciable loss of heat value provided the temperature is not allowed to rise above 180 degrees F." How near to this temperature a pile should be allowed to heat is largely a matter of judgment. If the rate of rise in temperature is decreasing rapidly, it may be safe to allow the temperature to approach 180 degrees, but if the rise is steady and regular it is wise to load out the pile before this danger point is reached. The extent of rise allowable also depends upon the means available for loading out. At a plant equipped with large grab buckets or other means for rapidly handling the coal a higher temperature can be permitted than in cases in which a considerable period is necessary to load out the coal. A person in charge of a certain kind of coal under certain climatic conditions will with a little experience be able to determine

* Porter, J. B., "Weathering of Coal," An Investigation of the Coals of Canada, Extra Vol., p. 159, 1915.

† "Effects of Storage Upon the Properties of Coal." Univ. of Ill. Eng. Exp. Sta., Bul. 97, pp. 7, 38, 1917.

the danger point. It is impossible to set any critical temperature which will apply to all coals under varying storage conditions. One very safe rule is to be ready to remove the coal if the temperature reaches 150 degrees F. and to load it out if the temperature rises to 175 degrees.

Water has often not proved effective in putting out fires, doubtlessly because of the fact that it was not applied in sufficient quantities to cool the entire mass thoroughly. An insufficient amount of water will aggravate rather than stop an incipient fire. One large pile in Chicago was soaked as completely as possible with streams from river fire tugs and while the fire was at the time apparently extinguished, it began burning again within two or three days. If the coal can be spread out and thoroughly saturated with water, the fire can be extinguished, but often there is not sufficient ground available to permit proper spreading.

In a private communication Dr. J. B. Porter says:

"I fully appreciate the fact that nearly everybody experienced in the storage of coal objects to the use of water for quenching fires in storage piles. I express scepticism as to the harmfulness of water quenching. Recent information strengthens this scepticism, and I have come across several cases of successful fire fighting by the intelligent use of water. The fuel agent of the Canadian Pacific Railway states that he always recommends the use of water if the fire is a small one, and particularly if it is detected in an incipient stage. His practice is to locate the hot spot by driving test rods into the pile and then to dig a pit one or two feet deep right over the center of trouble; to drive and pull pointed rods or open pipes from it down into the heating mass and then to fill the pit with water, thus quenching the fire at its very center. At the same time if the fire is a large one he surrounds the whole heated part with a water curtain made by digging a ring ditch one or two feet deep and perforating its bottom with a row of holes as in ventilation. This ditch like the central hole is kept full of water from the hose, and if there is any tendency for the fire to be driven outward from the center, it is quenched by the water curtain.

"This method of putting out a fire is of course costly, but it is enormously quicker and less costly than that of digging out and results in far less loss of material. Personally, I am confident that it will prove successful in any ordinary case."

Inert gases, such as carbon dioxide, have been tried as fire extinguishing agents.

16. *City Ordinances Affecting Storage.*—In order to determine if the heating of coal piles and the occasional fires resulting from them increase fire risks, letters were sent to the fire departments of

a number of cities. The following cities report that they have no city ordinances covering the storage of coal: Bloomington, Danville, Galesburg, Rockford, Decatur, Peoria, Illinois; Detroit, Michigan; Terre Haute, Indiana; Buffalo, New York; Superior and Milwaukee, Wisconsin; St. Louis, Missouri.

The Chief of the Fire Department of Toledo, Ohio, says: "We have no city ordinance governing the storage of coal, but have had several stubborn, but no disastrous fires in large coal piles due to spontaneous combustion."

J. C. McDonnell, Chief of the Bureau of Fire Prevention and Public Safety of Chicago, says:

"Every fall we have fires due to spontaneous combustion of coal in piles but this year they started earlier than usual. Since July 1, 1917 to date (November 14, 1917) there have been sixty-three fires in coal piles stored outside of buildings. The quantities involved varied from 20 to 15,000 tons. In fifty cases the pile laid in the open and in thirteen cases only a shelter roof was provided. There were for the same period thirty-nine fires in coal piles inside of buildings. Thirty of these interior fires were in apartment buildings and the amounts involved varied from 5 to 1,000 tons; stored in all cases on a concrete floor. In five of the inside fires provision was made for ventilating the pile by means of pipes. Some of the outside piles have been burning for three months and are still on fire. One large pile at the stockyards has completely changed itself into coke. Water has no effect on these fires. All the coal was a poor grade of soft coal."

The City of Chicago has the following ordinance:

"Coal—Storage in Buildings: Soft coal shall be stored away from the brick-work of boilers and furnaces and shall be kept only in incombustible rooms."

The following regulations covering fire insurance on coal docks show the points to be considered in connection with the construction and operation of such large storage plants:

"Standard Dock: Sand or earth filled, cement or concrete floor, with all iron or fireproof superstructure, and (or) storage sheds.

"Hoisting Apparatus: To be equipped with the 'Brown' or similar hoisting apparatus with automatic shovels or buckets known as the 'Clam' or 'Pick-up' type, for removal of coal in case of fire.

"Boilers: To be in fireproof house.

"Steam Pipes: To be free from wood or combustible material.

"Lubricating Oils: Must be limited to two barrels if in house exposing dock, sheds, or superstructure.

"Watchmen: To report through A. D. T. System of signal boxes to central station.

“Lighting or Power: If electricity, to be in accordance with rules of National Board of Fire Underwriters.

“Fire Protection: To be protected by city water and city fire department or private fire pump of at least five hundred gallons capacity per minute, supplying six-inch main extending entire length of dock, laid on ‘water’ dock so as to be properly drained, with sufficient number of hydrants and amount of 2½-inch hose attached or on cart to cover and reach all parts of the dock, also by standard fire boat service.

“Telegraph Fire Alarm: There shall be a telegraph fire alarm station or box within two hundred feet, with key at the dock.

“Fire Casks and Pails or Chemical Fire Extinguishers: Should be protected by an adequate number of fire casks and pails or approved chemical fire extinguishers (at least one at every Engine or Motor room on Dock or superstructure).

“Coal: A space of at least two feet at the base shall always be maintained between open piles of Bituminous Slack, Bituminous Coal, and Anthracite Coal.

“Anthracite coal piled or stored in frame covered or enclosed shed with bituminous coal shall take bituminous coal rate.

“Anthracite coal inside non-fireproof structure must be separated from bituminous coal or bituminous slack outside of said structure by at least two feet space at base of piles, and fifty feet space from non-fireproof structure containing bituminous coal or bituminous slack.

“Bituminous Slack Coal: Considering the disastrous experience on bituminous slack coal and the many fires resulting therefrom, it is not considered within the province of this schedule to name a rate thereon in any situation; and all policies covering bituminous coal should contain stipulation that the same is not intended to cover bituminous slack coal or screenings.

“Bituminous Coal: If placed on, in or within two feet, if dock is filled,—or within ten feet if dock is not filled,—of any frame building, shed, covered or enclosed superstructure (excepting loading pockets or loading bins), or of any anthracite coal or bituminous slack, add fifty cents to the base rate.

“Bituminous Slack: If placed on, in or within two feet, if dock is filled,—or within ten feet if dock is not filled,—of any frame building, shed, covered or enclosed superstructure (excepting loading pockets or loading bins), or any bituminous or anthracite coal, add one dollar to the base rate.”

V. STORAGE SYSTEMS

17. *Choice of a Storage System.*—In the choice of a storage system the following points should be considered:

(1) The location, size, and topography of the available storage ground.

(2) The capacity of the desired installation, that is, the amount of coal which it is desired to load and unload in a given time.

(3) The cost of the plant.

(4) The cost of maintenance.

(5) The cost of operation.

(6) The amount of breakage to be permitted in handling the coal.

(7) The way in which the coal is received, in open or box cars, or in boats.

(8) The length of time the coal must be kept in storage.

(9) Climate; in very cold countries under-water storage is impracticable for a part of the year.

The requirements of an ideal plant are:

(1) Adequate ground area, so that several sizes and varieties of coal may be stored separately. Separation into sizes has not been considered so important for bituminous as for anthracite coal, but it is becoming more important because of the increasing attention being given to preparation of coal for domestic use, and because of the fact that danger of spontaneous combustion is decreased by keeping different sizes separate in storage.

(2) Adequate facilities for rapidly and economically transferring coal from cars or from boats into storage.

(3) Adequate facilities for rapidly and economically reclaiming the coal and for rapidly moving any part of the pile which shows evidences of taking fire.

(4) Adequate track facilities, with gravity facilities, if possible, for handling cars.

(5) Means for preventing undue breakage in handling.

(6) Facilities for rescreening the stored coal, which, of course, increase the cost.

(7) Adequate available water supply.

(8) Low cost of installation, maintenance, and operation per ton of capacity. A storage plant is in operation very irregularly and costs are likely to be correspondingly higher because of the heavy fixed charges, especially interest and depreciation.

Few, if any, storage plants possess or require all these ideal conditions. In a coke plant, for instance, breakage need not be considered, except in connection with spontaneous combustion, since the coal is ground fine before being charged into the ovens. Storage facilities must of course be adapted to the various requirements and limitations in coal yards, power plants, railroad yards, boat docks, steel plants, and other establishments.

18. *Hand Operated Storage Systems.*—The simplest form of storage consists of dumping or shoveling the coal from a car or cart upon a pile or into a bin or bunker, or merely of dumping it on the ground. From this pile it may be shoveled directly into the furnace, or conveyed by wheelbarrow, scraper, or bucket line to the place of consumption. Under this classification may be included most of the systems of storage used by domestic consumers, retail coal yards, and small power plants. The equipment required for such a system is simple, and although it is sometimes the only system applicable to a given situation, it is not necessarily the cheapest form of storage.

The quantities stored in hand operated plants are relatively small, and the cost of storage is not usually separable from the other operating costs of the furnace or power plant. According to C. K. Baldwin,* "In transporting by wheelbarrows, gangs should be arranged to give room for the wheeler to load his own barrow. Should two men load with the wheeler idle, add thirty-five per cent to the time and cost of loading; when one loads with the wheeler, add twenty-five per cent. In carrying loads up and down a slope, add five per cent for each 4 degrees of slope. Hauling by wheelbarrows is more economical than by carts up to a distance of about 250 feet."

19. *Storage by Motor Truck.*—An interesting experiment is being carried on at the University of Illinois in the stocking of Illinois coal from Seam Number 6 at Georgetown under the general

* Marks, Lionel S., "Mechanical Engineers' Handbook," p. 1140, 1916.

supervision of J. M. White, Supervising Architect, and J. A. Morrow, Superintendent of Buildings. The annual consumption of the University is about 30,000 tons, the daily minimum being 50 tons and the maximum 150 tons. For several years it has been customary to stock from 4,000 to 5,000 tons on the ground in piles about twelve feet high. The coal is thrown by hand from railroad cars upon the pile, distributed by scrapers, and then hauled by wagons to the power house. At times fires have occurred in these piles.

At the present time an area 114 by 196 feet is being used, and since this space was formerly used for tennis courts, the base is of firm, smooth clay. The storage space has on three sides a plank fence seven feet high, the posts being tied by wire rope to pegs within the enclosure. When the enclosure is filled to a depth of fifteen feet it contains about 10,000 tons. This storage plat is about one thousand feet from the power house where coal is received and in which is located the machinery for the necessary crushing and screening of the coal prior to storage. The coal is dumped from coal cars into a track hopper from which it is elevated. When intended for storage, the coal is diverted from the bunkers which feed the boilers. If the coal consists of screenings or the size of lump desired for storing, the railroad car dumps it into a pit from which it is elevated to a bin and then discharged into an end dumping motor truck. If lump coal or a size not desired for storing is received, it is crushed, if necessary, and screened; then by means of the storage truck which holds $3\frac{1}{2}$ tons it is taken to the storage ground. An illustration of the storage ground is shown as Fig. 2.

At the storage plat a truck running on the ground first builds up a bed of coal from two to five feet thick from the fence toward the center as shown in Fig. 3. When this center becomes too small to provide space for handling the truck, the operation continues on top of the first layer already in place as shown by Fig. 4, and a second layer is similarly deposited, the bed thus being built layer upon layer. To permit the truck to work on top of the pile of coal a track is built of pieces of scrap plank, two by three feet, woven together with galvanized wire or cable, as shown in Fig. 2. The cable is more flexible but more costly than the wire. This track is in sections, of from five to eight feet, and two lines are laid on which the truck runs. A track of wire fencing has been tried, but it is not stiff enough to provide a satisfactory running base for the truck.

An effort is made in storing the coal to have it thoroughly packed and to exclude the air as much as possible. Regular temperature observations are taken with an iron rod. This method differs from the ordinary pile storage in the tamping of the fine coal to exclude the air, and the experiment is being watched with a great deal of interest.

A plank track for the truck is laid between the storage pile and the power house, and by rapid loading and fast driving a round trip is made in from seven to eight minutes; thus nineteen tons are stored per hour. Three men are used on the pile for cleaning out the truck and spreading the coal. The coal is separated into two parts, screenings being placed on one side of the storage space and lump coal on another, but the two piles come together. The coal is reclaimed with an electrically operated Jeffrey wagon and truck loader (Fig. 5).

The expenses of handling are given in the following statement:

EXPENSE OF HANDLING COAL AT UNIVERSITY OF ILLINOIS POWER PLANT

Expense of labor for unloading coal per ton by hand from flat bottom cars at hopper with labor at 25 cents per hour.

Lump Coal	\$0.10
Screenings	0.08

(With Motor Truck Based on 15 Tons per hour and on Two Blocks Haul.)

Expense of labor and teams for loading screenings by hand and hauling in wagons from storage pile to track hopper 300 to 500 feet away, per ton.

Labor	\$0.13
Team	0.07
Total	\$0.20

Expense of labor and team for unloading screenings from bottom dump cars to hopper and for loading wagons from overhead bunker and hauling to storage pile, 300 to 500 feet away, per ton.

Labor	\$0.08
Team	0.03
Total	\$0.11

One team will haul 20 tons per hour to storage if loaded from overhead bunker and will return $7\frac{1}{2}$ tons per hour from storage pile to hopper if loaded by hand.



FIG. 2. COAL STORAGE PLAT AND STORAGE PILE AT THE UNIVERSITY OF ILLINOIS



FIG. 3. PLACING THE FIRST LAYER OF COAL ON STORAGE PLAT AT THE
UNIVERSITY OF ILLINOIS



FIG. 4. PLACING THE SECOND LAYER OF COAL ON STORAGE PILE AT THE
UNIVERSITY OF ILLINOIS

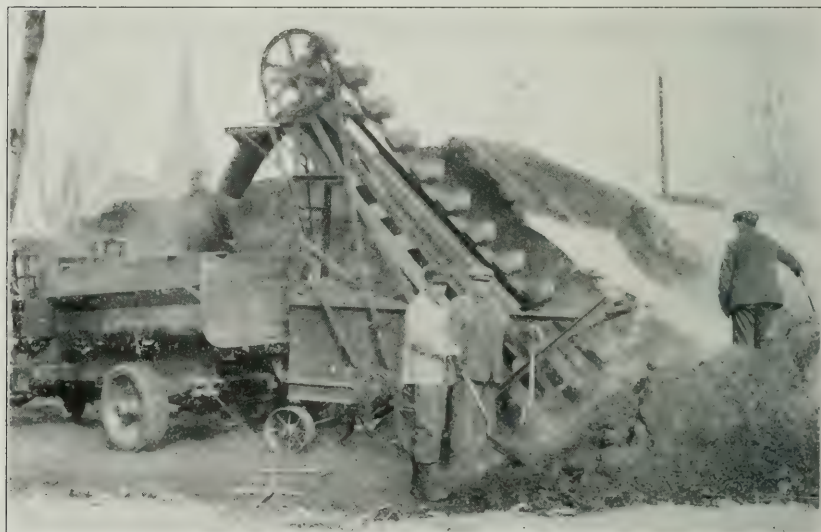


FIG. 5. ELECTRICALLY OPERATED WAGON AND TRUCK LOADER USED AT THE
UNIVERSITY OF ILLINOIS



FIG. 6. RAILROAD STORAGE PILE SHOWING TRACK



FIG. 7. RAILROAD STORAGE PILE SHOWING CRIB FOR SUPPORTING TRACK



FIG. 8. RAILROAD STORAGE PILE SHOWING MEN AT WORK RAISING TRACK
THIS PILE CONTAINS 25000 TONS OF COAL

Expense of Storing Coal with Truck
(Truck will handle nineteen tons per hour)

Expense of hauling coal with truck	\$0.08
Expense of trimming pile, building roads, etc., ...	0.06
Expense of unloading lump coal by hand from flat bottom cars, crushing, elevating, and loading trucks	0.20
Expense of unloading screenings by hand from flat bottom cars, elevating, and loading trucks	0.13
Expense of unloading screenings from bottom dump cars, elevat- ing, and loading trucks	0.07
Total	\$0.21—0.34

Expense of Removing Coal from Storage

1 Man running loader at 30 cents per hour	\$0.30
1 Man running truck at 30 cents per hour	0.30
1 Man leveling load at 30 cents per hour	0.30
1 Man at top of pile at 30 cents per hour	0.30
2 Men at plant hopper at 30 cents per hour	0.60
2 Men at feeding loader at 30 cents per hour	0.60
Truck operation and maintenance	0.60
Total expenditure per hour	\$3.00
Expenditure per ton	0.20

20. *Pile Storage from Cars without a Trestle.*—A method of storage commonly used by railroads consists of starting a pile on the ground, and raising the track gradually on top of the coal pile until a height of from ten to twenty feet is reached, the end of the track being supported on a crib as shown in Figs. 6 and 7. Fig. 8 shows such a coal pile with men raising the track. The coal is reclaimed with a locomotive crane, with a steam shovel, or by hand shoveling into cars. This is a simple form of storage, but the conditions are favorable to spontaneous combustion, because the weight of the locomotive and the loaded cars breaks up the coal and produces fine material in the center of the pile, while the lumps roll to the bottom of the outside slope and thus afford a flue through which the air may reach the fine material.

Figs. 6 and 7 show the effect of dumping side dump cars which were evidently so loaded that the lumps were on one side and the fine coal on the other. The north side of the pile, Fig. 7, contained fine coal and the south side, Fig. 6, the lumps. This pile took fire in several places and always on the fine coal side.

21. *Trestle Storage*.—Trestle storage consists of storing coal by dumping it from railroad cars run upon a trestle underneath which is located a storage bin. This method of storage is extensively used by large retail dealers and by factories and power plants. The coal is reclaimed by hand, by steam shovels, by locomotive cranes, by washing with water into conveyors, or by other suitable mechanical means. Although simple in construction and low in cost of the equipment, trestle storage produces excessive breakage, and unless drop bottom cars are available the expense of unloading by hand is high. It also requires considerable space if coal cars are to be pushed up an incline by a locomotive, or if some hoisting device must be installed.

Fig. 9 shows such a trestle arrangement in connection with a locomotive coaling station as suggested by the International Railway Fuel Association.

Fig. 10 shows two systems of trestle storage and of reclaiming by means of a tunnel, which may be either above or below ground, the coal being fed by gravity into a car or into some form of a conveyor in the tunnel. The breakage is excessive, both in stocking and in removing coal.

The introduction of a reloading tunnel decreases the cost of handling considerably, but with the tunnel above ground only from 30 to 35 per cent of the coal may be reloaded by gravity. With the tunnel underground about 50 to 60 per cent may be thus loaded directly. The cost of an underground tunnel plant is estimated as from 65 to 75 cents per ton storage capacity, and if the trestles are built of timber the expense of repairs and maintenance is considerable. A trestle and tunnel system using buckets for unloading and reloading the coal has certain advantages over the car system, but is limited in its capacity to from 500 to 5000 tons.

The amount of storage space may be increased by the building of bulkheads along the sides of piles as shown in the upper sketch of Fig. 10.

According to Norris,*

“An early type of storage-plant consists of wooden bins (Fig. 11) traversed by railroad tracks, from which the various sizes and types of coal are dumped, each in its appropriate bin. Reloading is usually accomplished by cars passing under the bins, either on the surface or more frequently in tunnels.

* “The Storage of Anthracite Coal.” Trans., Am. Inst. of M.-E., Vol. 38, p. 340.

“To reduce the danger from fire, the movement of the reloading-cars is usually by gravity or by rope-haulage. The individual bins are necessarily limited in capacity to from 50 to 100 tons each, and an extensive plant covers a very large area. One such plant at the seaboard has 384 bins, reloading into cars in nine tunnels, and covers approximately nine acres. Such a plant costs in excess of three dollars per ton of capacity to erect, requires an enormous amount of timber, with resulting large fire-hazard and high maintenance-charges, and the operating expenses approach ten cents per ton.

“A great advantage is the practicability of storing many sizes and kinds of coal, and keeping separate many small consignments.”

The following formulas and table are used by the Link-Belt Company for determining the horizontal pressure of a pile of bituminous coal against a retaining wall. This pressure depends upon

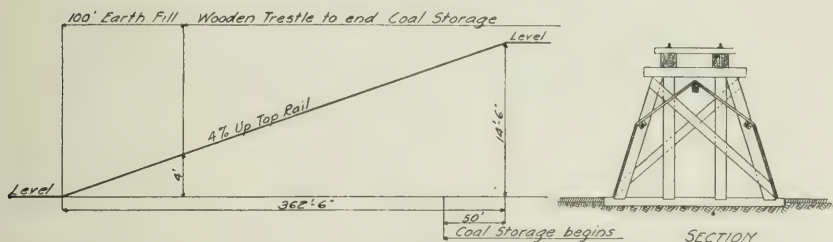


FIG. 9. TRESTLE FOR COAL STORAGE AS SUGGESTED BY FUEL STATION COMMITTEE OF THE INTERNATIONAL RAILWAY FUEL ASSOCIATION

the weight of the coal per cubic foot (assumed to be fifty pounds) and the depth of the material at the wall, and the slope of the surface of the pile.

For bituminous coal, let d represent the depth in feet. Then with surface of pile horizontal:

Total pressure in pounds on wall per foot of length $= 6.37d^2$

Pressure on wall on lowest foot of depth $= 6.37 (2d-1)$

With surface of pile sloping:

Total pressure in pounds on wall per foot of length $= 10d^2$

Pressure on wall on lowest foot of depth $= 10 (2d-1)$

Angle of repose $= 35$ degrees.

Table 3 gives these pressures in pounds for bituminous coal for every foot of depth up to 50 feet.

TABLE 3
HORIZONTAL PRESSURE EXERTED BY BITUMINOUS COAL AGAINST VERTICAL
RETAINING WALLS PER FOOT OF LENGTH

Depth in Feet	Horizontal Surface		Sloping Surface		Depth in Feet	Horizontal Surface		Sloping Surface	
	Total Pressure Pounds	Pressure Pounds Lowest Foot	Total Pressure Pounds	Pressure Pounds Lowest Foot		Total Pressure Pounds	Pressure Pounds Lowest Foot	Total Pressure Pounds	Pressure Pounds Lowest Foot
1	6.4	6.4	10	10	26	4,305	325	6,760	510
2	25.0	19.0	40	30	27	4,641	338	7,290	530
3	57.0	32.0	90	50	28	4,993	350	7,840	550
4	102.0	45.0	160	70	29	5,358	363	8,410	570
5	159.0	57.0	250	90	30	5,733	376	9,000	590
6	229.0	70.0	360	110	31	6,122	389	9,610	610
7	312.0	83.0	490	130	32	6,523	401	10,240	630
8	407.0	96.0	640	150	33	6,935	414	10,890	650
9	516.0	108.0	810	170	34	7,362	427	11,560	670
10	637.0	121.0	1,000	190	35	7,778	440	12,250	690
11	770.0	134.0	1,210	210	36	8,253	452	12,960	710
12	917.0	146.0	1,440	230	37	8,754	465	13,690	730
13	1,076.0	159.0	1,690	250	38	9,193	478	14,440	750
14	1,248.0	172.0	1,960	270	39	9,682	490	15,210	770
15	1,433.0	185.0	2,250	290	40	10,192	503	16,000	790
16	1,630.0	197.0	2,560	310	41	10,669	516	16,810	810
17	1,840.0	210.0	2,890	330	42	11,236	529	17,640	830
18	2,063.0	223.0	3,240	350	43	11,797	541	18,490	850
19	2,298.0	236.0	3,610	370	44	12,331	554	19,360	870
20	2,548.0	248.0	4,000	390	45	12,968	567	20,250	890
21	2,809.0	261.0	4,410	410	46	13,478	580	21,160	910
22	3,083.0	274.0	4,840	430	47	14,100	592	22,090	930
23	3,369.0	287.0	5,290	450	48	14,679	605	23,040	950
24	3,669.0	299.0	5,760	470	49	15,275	618	24,010	970
25	3,981.0	312.0	6,250	490	50	15,925	631	25,000	990

NOTE.—Weight of coal is taken as 50 pounds per cubic foot in calculating this table.

In the parallel trestle system (Fig. 12) two parallel trestles from ten to fifteen feet high are located about thirty feet apart. A locomotive crane runs on one of these trestles, unloads coal from railroad cars on the other trestle, and deposits it for storage in a pile the length of which is limited only by the length of the trestle. The crane and the cars are used interchangeably on the trestles so that the storage system consists of parallel piles. A pile of anthracite twenty-five feet high, whose angle of repose is 27 degrees, contains sixty-seven tons per running foot. For bituminous coal a pile of the same height, with an angle of repose of 40 degrees, contains 63 tons per running foot.

22. *Storage with Side Dump Cars.*—The Chicago, Wilmington and Franklin Coal Company at the Orient Mine, Franklin County, Illinois, has installed a very simple but effective storage system designed by G. B. Harrington, President of the Company, in which side air dump contractors' cars are used. These cars hold twelve cubic yards, but with sides built twice the usual height they have a capacity of about twenty-five tons of coal. In a level field located a short distance from the tippie, an elevated track was built, as shown in Fig. 13, from which the side dump cars empty the coal alongside the

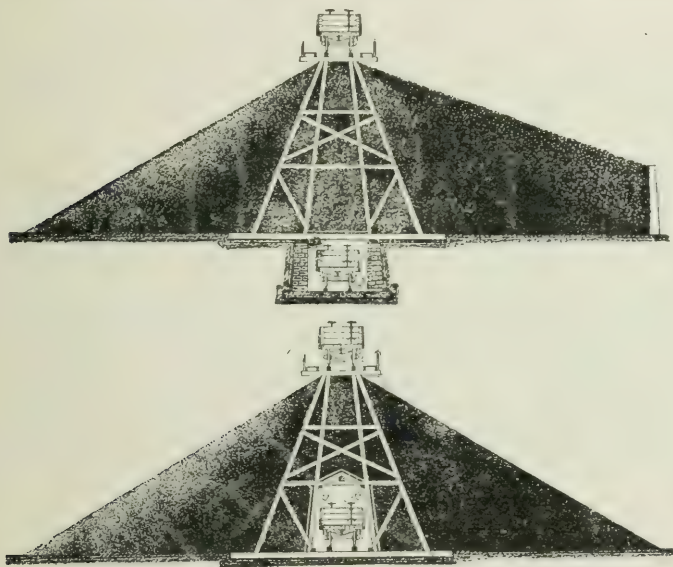


FIG. 10. TRESTLE AND TUNNEL SYSTEMS, SHOWING AN ABOVE-GROUND AND A BELOW-GROUND TUNNEL

track. Two locomotive cranes with two-yard clam-shell buckets, one on each side of the trestle, move the coal into storage piles parallel with this main elevated track. The dump cars are loaded at the tippie, as shown in Fig. 14.

The purpose of this plant is to permit continuous operation of the mine on days or parts of days when there is a failure in the railroad car supply and the mine would otherwise have to shut down. When railroad cars are scarce, the air dump cars take the output to the storage trestle. The cranes move the coal back into the storage piles

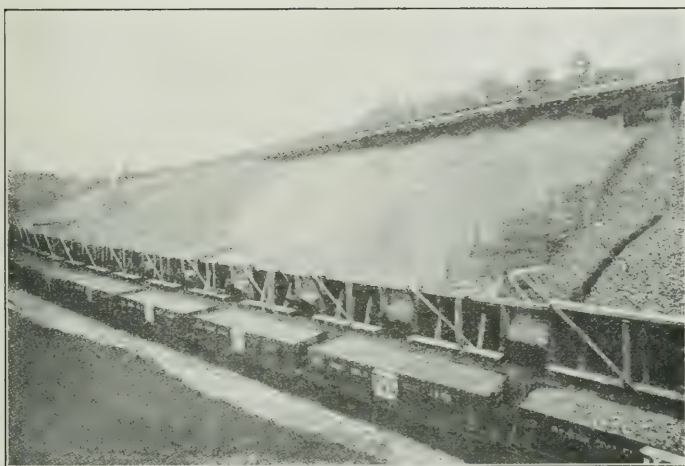


FIG. 15. SIDE HILL SYSTEM OF STORAGE

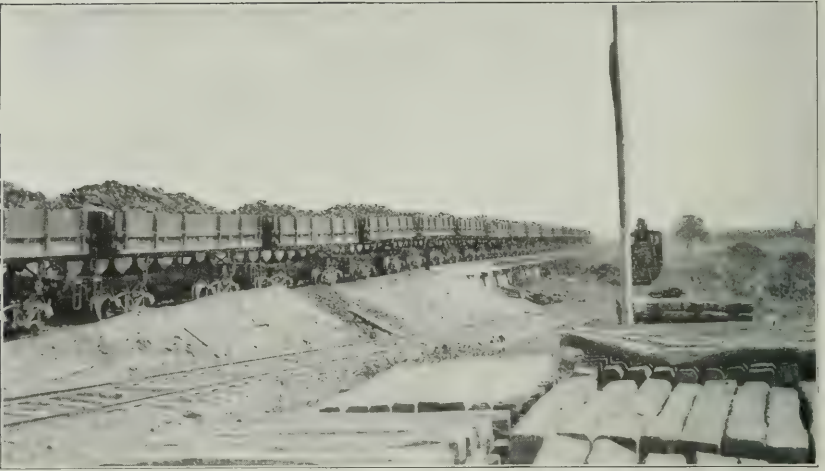


FIG. 13. STORAGE TRACK AND SIDE DUMP CARS AT THE ORIENT MINE OF THE CHICAGO, WILMINGTON AND FRANKLIN COAL COMPANY

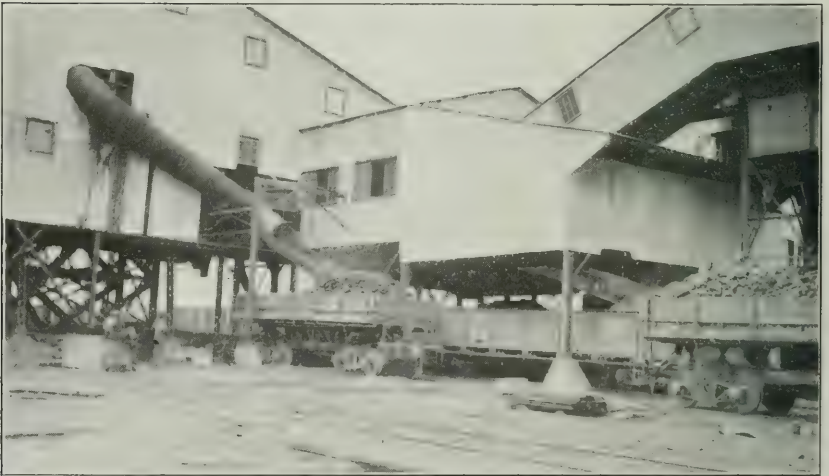


FIG. 14. LOADING DUMP CARS AT THE TIPPLE, ORIENT MINE OF THE CHICAGO, WILMINGTON AND FRANKLIN COAL COMPANY

When not in use for storage the dump cars and cranes are useful in handling refuse, ashes, machinery and equipment, and for grading and other work at the mine.

The capacity of the Orient No. 1 Mine is from 4,500 to 5,000 tons a day, and the storage equipment described has proved effective in

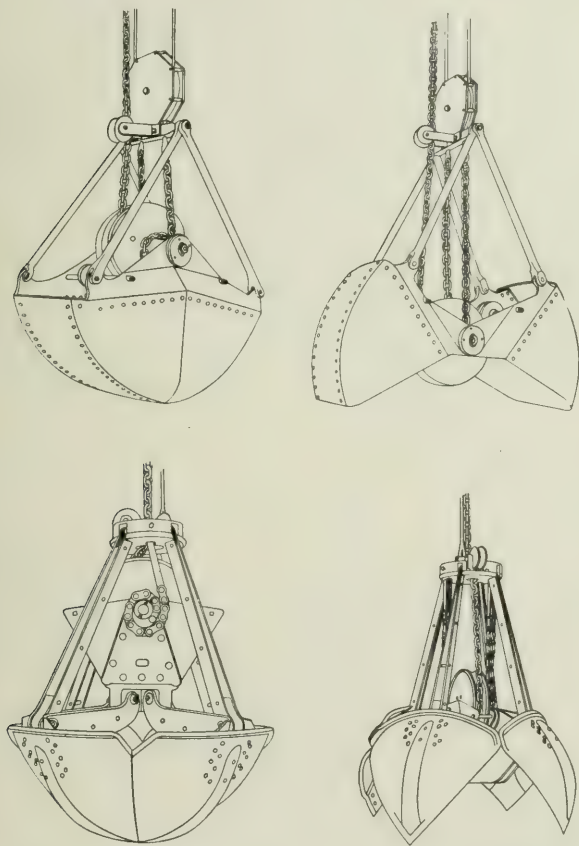


FIG. 16. CLAM-SHELL BUCKET (TOP) AND ORANGE-PEEL BUCKET

helping to maintain a fairly uniform output with an inadequate and irregular car supply. It takes about thirty minutes to load a string of fifteen dump cars at the tippie, to run them down to the storage trestle about a mile away, to dump them, and to return the empty cars to the tippie. The trestle and track hopper are designed to

save unnecessary breakage and the coal shows practically no degradation in the few days during which it is held in storage.

In normal times these dump cars cost about \$1,350.00 each and the cranes about \$5,800.00 each. The trestle used is about nine feet high and costs about nine dollars per running foot.

A number of other varieties of dump cars has recently been used for similar storage purposes at other plants. In one instance all steel cars of thirty cubic yards capacity have been substituted for the smaller cars.

23. *Side Hill Storage.*—In the side hill system of storage (Fig. 15) a steep hill side is utilized, and coal is unloaded by gravity from cars on a track or trestle at the upper side of the storage yard. At the bottom of the pile a retaining wall holds back the coal, and below this cars are loaded by chutes running into the pile. In order to increase the capacity of such a plant a level space is usually provided back of the retaining wall, but this produces a dead space from which the coal must be shoveled and in which when using the chutes a large amount of coal is left as dead stock. While side hill storage appears to be ideal in its arrangement and possibilities, there are comparatively few situations in which it can be applied conveniently and profitably.

24. *Self-filling Buckets.*—The type of bucket used for handling coal in connection with locomotive cranes, traveling bridges, and other mechanical storage devices is a matter of some importance. Coal must be handled quickly and in such manner as to prevent excessive breakage.

The two types of self-filling buckets most generally used in the handling of coal are the so-called clam-shell and orange-peel types (see Fig. 16). Both types are reported to be satisfactory.

25. *Use of Mast and Gaff Arrangement in Storage.*—In the simpler forms of coal handling machinery the ordinary mast and gaff arrangement (Fig. 17) is cheap and efficient when rapidity of handling and maximum storage are unnecessary.

The traveling cableway (Fig. 18) is more efficient so far as utilization of ground area is concerned but is slow in stocking and reclaiming where long lengths of travel are necessary.

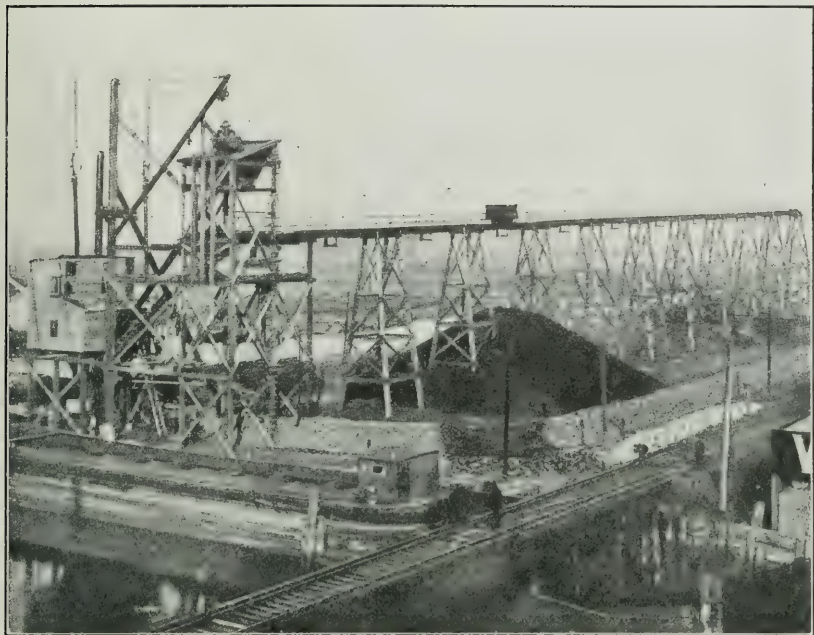


FIG. 17. AUTOMATIC GRAB ON MAST AND GAFF WITH SHUTTLE CABLE RAILWAY

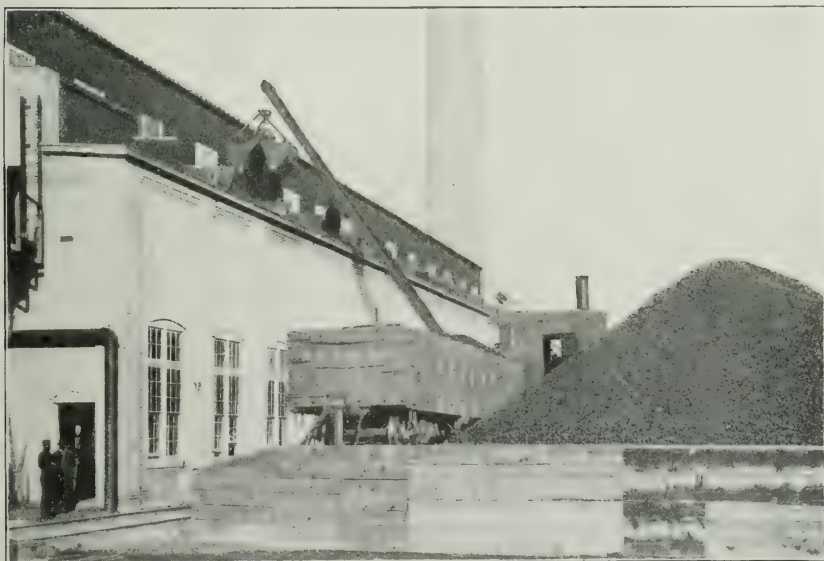


FIG. 19. LOCOMOTIVE CRANE WITH CLAM-SHELL BUCKET UNLOADING COAL

26. *Locomotive Crane Storage.*—The device most generally used for storage except when very large special equipment is necessary, is the revolving locomotive crane equipped with a clam-shell or orange-peel bucket. Locomotive cranes are used particularly in large industrial plants.

Fig. 19 shows a locomotive crane operating from a low trestle and placing coal either into the bunker or on stock pile.

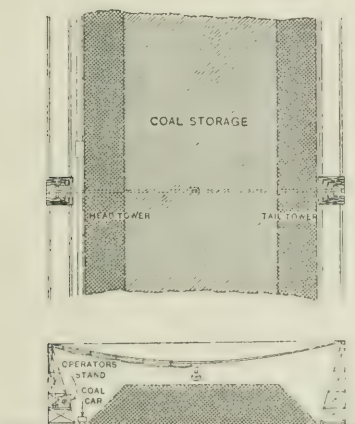


FIG. 18. TRAVELING CABLEWAY

These cranes are self-propelled at the rate of from four to eight miles per hour, and may also be used for shifting cars over small distances, thus eliminating the necessity of a locomotive. They are generally operated by steam, although sometimes electric power is employed. The revolving superstructure is supported on a base which rests on four to eight wheels, the eight wheeled car body being preferable for switching and for general work. The gage of the track on which these cranes run may have to suit existing conditions at any one plant, but when choice is possible the gage should be approximately as follows:

- 4 feet, 8½ inches for a maximum radius of swing of 30 feet.
- 14 feet, 6 inches for a maximum radius of swing of 45 feet.
- 16 feet for a maximum radius of swing of 60 feet.
- 20 feet for a maximum radius of swing of 100 feet.

The operator, who is on the covered platform, fills the bucket, and as he raises it the crane revolves to the unloading point. The speed of operation varies greatly with the operating conditions, but the speed generally averages about one bucket per minute.

Prices of machinery quoted during war times may be misleading, since they are generally higher than in normal times and they vary so rapidly that any quotation given by a manufacturer holds for only a short time. On account, however, of the extensive use of the locomotive crane for storing coal the following prices quoted by several firms in April, 1917 are presented:

(1) Standard 14-ton, 4-wheel steam locomotive crane with boom 35 feet, 4 inches long and double drums for operating a 54-cubic-foot grab bucket, f. o. b. Champaign, \$11,475. This crane will handle from $1\frac{1}{4}$ to $1\frac{1}{2}$ tons per minute, and under average operating conditions should easily make from sixty to ninety bucket trips per hour.

(2) Fourteen-ton, 4-wheel steam locomotive crane with boom 40 feet, $9\frac{1}{2}$ inches long, and double drums, for handling a 40-foot grab bucket, f. o. b. to Champaign, \$11,515. This crane will handle from 1800 to 2000 pounds per minute at about the same rate as crane (1).

(3) Standard 8-wheel crane with boom 40 feet, $9\frac{1}{2}$ inches, and double drums for handling a 54-cubic-foot grab bucket, \$14,600.

For a small amount of travel the 4-wheel crane will handle as much coal per day as the 8, but on account of its rigid base it is not as suitable for moving cars on curves or over general yard tracks.

(4) Fifteen-ton, 8-wheel crane with boom 40 feet, $9\frac{1}{2}$ inches to handle a 50-cubic-foot bucket at 40-foot radius, net shipping weight 100,000 pounds, \$14,600.

(5) Similar but heavier crane to handle 40 cubic feet at 50-foot radius, \$14,960.

(6) Standard gage steam operated revolving locomotive, 8-wheel double track crane with 50-foot boom, and two-cubic-yard clam-shell bucket, \$14,300.

(7) Standard gage steam operated revolving locomotive crane, 4-wheel 42-foot boom 2-cubic-yard clam-shell bucket, \$11,893.

J. S. Shearer, of the Industrial Works, Bay City, Michigan, says:

"In some cases a crane with a 45-foot boom is able to unload the far end of the car standing on the same track as the crane. At the present time, however, when cars are being made longer than before, we find it to be almost always the case that a boom giving a radius of fifty feet is necessary. If a crane is to work on a track parallel with one from which the coal is to be taken a shorter boom is, of course, possible.

"We formerly figured on the daily operating cost as approximately one dollar an hour. This contemplates using the crane ten hours a day and in the cost are included the services of an engineer, a helper on the ground, interest, depreciation, fuel, supplies, and repairs. At the present time when the first cost of equipment is higher and the cost of all supplies higher, we think you would have to take \$1.50 to \$2.00 an hour as the approximate charge. Under average operating conditions the crane would have no difficulty in handling from forty to seventy-five tons per hour. This would make the cost per ton somewhere around three cents. We formerly found that the cost averaged about two cents, sometimes being less and sometimes more."

The Storage of Coal Committee of the International Railway Fuel Association* says with regard to storing with a locomotive crane:

"We would suggest the employment of a locomotive crane with clam-shell or similar device for unloading and reloading storage coal, where the amount to be stored is less than five thousand tons and where the daily issues are small enough to permit of its use. This arrangement requires no preliminary preparation and little or no additional expense. The cost of unloading from the road cars may be cheapened when dump bottom cars are available, by unloading them on tracks that have been blocked upon old car and bridge timbers, so placed and arranged that the structure can be raised bodily from time to time, by the use of a locomotive crane, working on an adjacent and parallel track."

The ways in which a locomotive crane may be used in connection with storage of coal are numerous, and only some of the typical ones will be given. Catalogs of the manufacturers of these cranes are the best source of information regarding their uses.

At the coal yards of the Commonwealth Edison Company a locomotive crane with a two-yard clam-shell bucket will ordinarily unload from ten to fifteen cars per day of eight hours. One operator has loaded as many as twenty-five cars in ten hours. The amount is less in cold weather and in handling large coal. Two men are employed on the crane, and two shovel out the cars and clean the track. The crane can load faster than it can unload the cars.

According to W. L. Abbott, Chief Engineer of the Commonwealth Edison Company of Chicago, that company aims to keep in storage

* "Storage of Coal." Proceedings, Vol. VII, p. 152, 1915.

at its various city stations from 100,000 to 150,000 tons of coal and at the Glenn storage yards, outside the city limits, about 260,000 tons. All varieties of Illinois coal are stored, but those of southern Illinois are preferred. Coal is placed in storage and reclaimed by locomotive crane at an estimated expense of five cents per ton for unloading and five cents for reclaiming. This covers labor and materials only.

According to the storage scheme devised by Mr. Abbott, coal is stored on the ground in continuous pyramidal piles twenty-five feet high, each pile being between and parallel with two pairs of railroad tracks, as shown in the upper sketch, Fig. 20. The tracks bounding

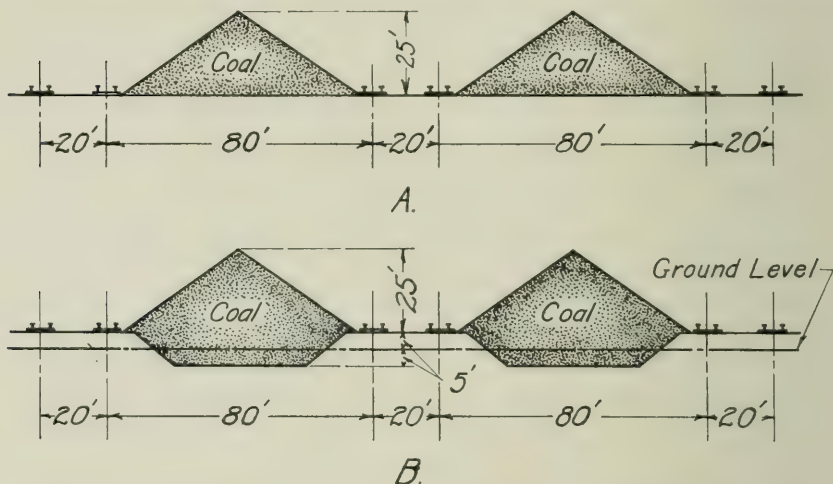


FIG. 20. ARRANGEMENT OF TRACKS AND STORAGE PILES EMPLOYED BY THE COMMONWEALTH EDISON COMPANY IN OPEN STORAGE

the piles are eighty feet, center to center, and the tracks between the piles twenty feet, center to center. The crane can operate from either track while loading or unloading cars on the parallel track. These piles contain about thirty tons per foot of length.

This company is now preparing a new storage yard for the accommodation of 120,000 tons of coal in which the general arrangement will be similar to that shown in the upper view, Fig. 20, with the difference that the ground under the coal space will be excavated to a depth of five feet below the surface, and the spoil will be used to raise the grade of the tracks five feet above the ground level, thus render-

ing possible a coal pile of a total depth of thirty-five feet and containing forty-five tons per foot of length, as shown in the lower sketch, Fig. 20.

27. *Parallel Track Storage.*—Fig. 21 shows a double track storage arrangement for a locomotive coaling station, the coal being piled between the parallel tracks, and loaded and unloaded with a locomotive crane.

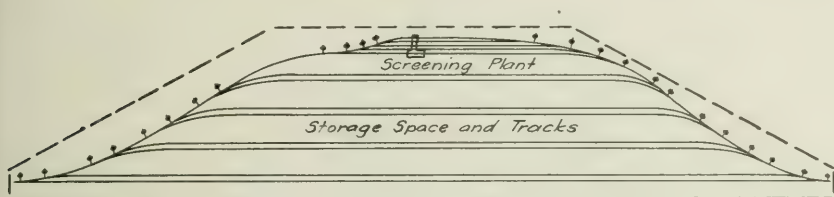


FIG. 21. PARALLEL TRACK STORAGE SYSTEM

(Reprinted from the Proceedings of the International Railway Fuel Association)

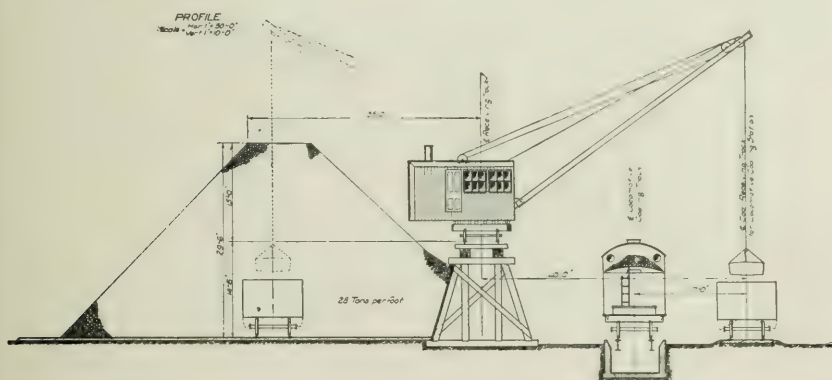


FIG. 22. RAILWAY TRESTLE AND CRANE SYSTEM OF STORAGE

(Reprinted from the Proceedings of the International Railway Fuel Association)

28. *The Trestle and Crane System.*—Fig. 22 shows a combined trestle and locomotive crane system suggested by the Fuel Station Committee of the International Railway Fuel Association. A timber trestle erected adjacent to the track on which locomotives are coaled and fireboxes cleaned provides a runway for a locomotive crane equipped with a clam-shell or grab bucket.

The Committee* states:

"It is advisable to place a plank wall or barrier along the side of the trestle contiguous to the storage pile, to prevent coal from accumulating under the trestle, thus obviating the necessity of reclaiming such accumulation by the employment of laborers.

"Adjoining the trestle, sufficient ground is reserved for the storage pile, which will require a strip of land about sixty feet wide, and varying in length in proportion to the capacity of the pile.

"The plan provides for a storage capacity of twenty-eight tons per lineal foot of coal pile.

"The operation of this plan is as follows:

"Coal will be delivered to the coal-receiving track in gondola cars of practically any type, from which it will be removed and transferred to the storage pile by the locomotive crane.

"When it is desired to reclaim the storage coal, the foregoing operation is reversed, the crane picking up the coal from the pile and reloading it in cars, which are then hauled away to be discharged at any of the coaling stations served by the storage plant. Or, if desired, this plant may be used for coaling engines either from cars on the receiving track or from the storage pile. It is not considered advisable to use this plant as a locomotive coaling station at terminals where a large number of engines are coaled, as delay might be caused in the rapid movement of engines, due to the comparative slowness of the crane as a coaling device. In the event of a serious breakdown in the coaling station, the crane would afford a very good emergency device for coaling engines while repairs were being made to the coaling station.

"From somewhat meager figures available it is estimated that coal can be stored from cars, or reloaded from storage at about two and one-half cents per ton."

Fig. 23 shows a McMyler locomotive crane placed on an elevated traveling platform.

The Clinchfield Fuel Company with mines at Dante, Va., has a storage plant at Spartanburg, S. C., which has a capacity of 150,000 tons and in which from 10,000 to 130,000 tons are kept in storage for periods of from six months to two years. The storage plant is 994 feet by 240 feet with a railway running through the center of the storage space. On each side of this trestle are tracks for a traveling crane. The trestle is approximately twenty feet high and incoming coal is dropped through this trestle from hopper bottom cars. A McMyler traveling crane with a 75-foot boom and a 2.5-ton grab bucket picks up the coal from the foot of the trestle and piles. The crane has a capacity of two hundred tons per hour.

The storage space is floored with two-inch planks nailed securely to timbers. The tops of these timbers are set flush with the ground level.

* "Storage of Coal." Proceedings, International Railway Fuel Association," Vol. VII, p. 156, 1915.

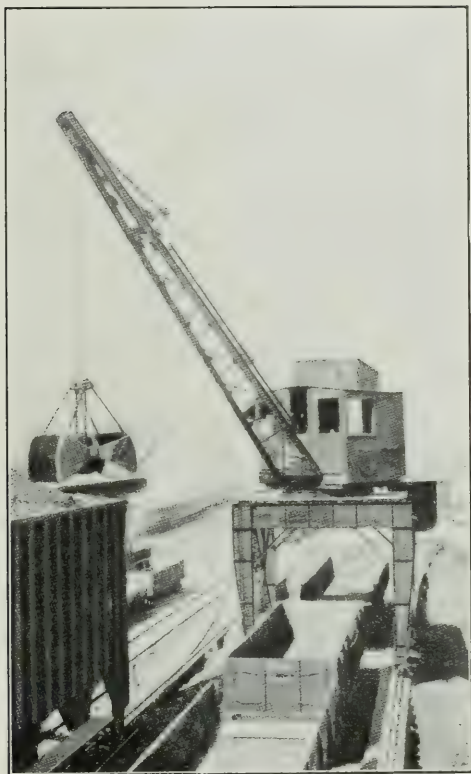


FIG. 23. LOCOMOTIVE CRANE PLACED ON AN
ELEVATED TRAVELING PLATFORM

The pile is continuous, and from thirty to forty feet high. The expense of storing is as follows:

Unloading or Storing Expense, June 24–October 4, 1912, including pay roll, repairs, supplies, power, depreciation at 10 per cent per annum and interest at 5 per cent.	\$8441.
Tons handled 125,696; expenditure per ton	\$0.0671
Reloading expense, October 8, 1912–January 31, 1913 . . .	\$8496.
Tons handled 129,778; expenditure per ton	0.0655
Total average expense of storing and reclaiming at 13.26 cents per ton. Unloading expenses May 1–August 1, 1914, tons handled 131,949; expenditure per ton	0.0618

The coal is from Russell County, Va., and is run of mine with about sixty per cent lump over a two-inch screen. No attempt is made to remove slack. It has the following composition:

	Per cent
Moisture	2.8
Volatile Matter	34.9
Fixed Carbon	56.6
Ash	5.8
Sulphur	.6
B. t. u.	14150

It is placed in storage about six to ten days after being mined and during the summer time; thus the surplus from the mine is stored when the demand is below the output of the mine, provides for extra demand in winter, and insures customers against strikes and other contingencies.

There is no difference in the price of stored and fresh coal. In fact storage coal is sometimes higher because of "spot" demand. No material decrease in heating value is noted, but there is a decrease of ten per cent in lumps. Slight heating occurs after three or four months, and in some cases reaches 170 degrees F. The temperature is tested by tubes placed in each pile. No means, however, are taken to prevent heating, but if it occurs the coal is loaded out at once and shipped.

29. *Circular Storage.*—The peculiar adaptability of the locomotive crane to operation in a circle and its easy portability have led to a number of so-called circular storage systems. Some of these have been patented by the J. M. Dodge Company. Fig 24 illustrates a

Dodge type of circular system with a capacity of from 6,000 to 40,000 tons. The coal is dumped from a railroad car into a track hopper from which it is taken by a long radius locomotive crane and self-filling bucket and dumped upon piles, the circular crane track being finally completely covered. A number of piles may be joined, as shown. In reloading, the crane takes the coal from the pile and loads it directly into the car. The rate of handling in such a storage system

	Stocking	Reclaiming
Labor and supplies per ton	\$0.025	\$0.014
Power and, superintendence	0.016	0.014
	\$0.041	\$0.028

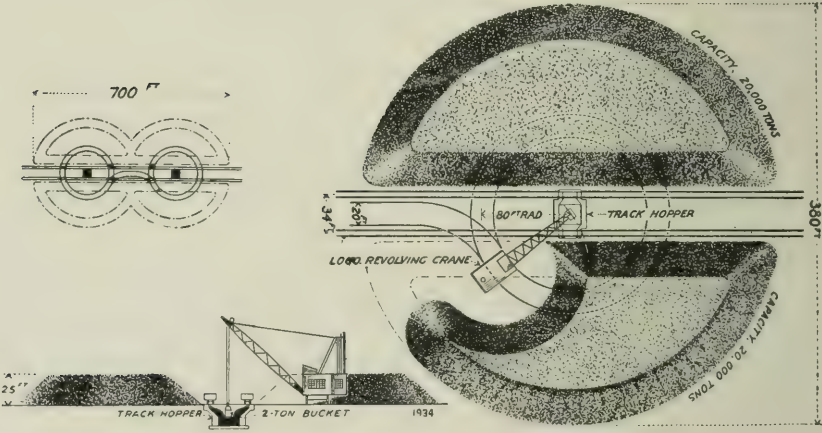


FIG. 24. DODGE TYPE OF CIRCULAR STORAGE SYSTEM

varies from 40 to 200 tons per hour, according to the size of the bucket and crane used. The length of the boom depends upon the storage capacity required. The estimated expense of operation is as follows:

An elaboration of this system by which concentric storage piles may be built up is shown by Fig. 25. By rehandling the coal in such a system from one pile to another an almost unlimited capacity may be secured.

Table 4 gives the storage capacity with this system for cranes of different radii and for the two conditions, first where the crane tracks are covered, and secondly, where the crane trucks are left uncovered. The railroad tracks are assumed to be twenty-seven feet center to center and the coal to weigh fifty pounds per cubic foot.

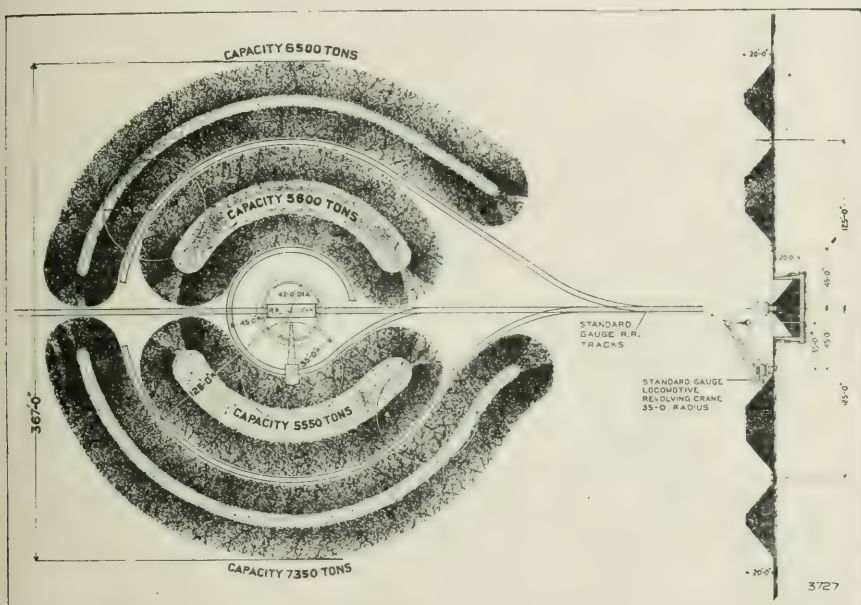


FIG. 25. TWENTY-FIVE-THOUSAND-TON STORAGE PLANT

The storage plant of the Old Ben Coal Corporation at its No. 9 Mine at West Frankfort, Franklin County, Illinois, (Fig. 26) is a modified circular storage. At this mine five sizes of coal are prepared for the market by means of spiralizers and seven sizes are shipped.

When there are no cars for direct shipment, the coal instead of being deposited in the shipping bins, *aa*, is carried by the apron conveyors, *bb*, delivered to a cross conveyor, *c*, and then deposited by the chute, *d*, upon the pile, *e*. It is then taken by a locomotive crane, *f*, which has a boom 110 feet long operating over a 100-foot radius. The capacity of the plant is about 300,000 tons. By means of an additional track outside the storage pile, the capacity could be greatly increased.

TABLE 4
CAPACITY OF CIRCULAR CRANE STORAGE
(Link-Belt Company)

Radius of Crane (Feet)	Crane Tracks Covered (Feet)						
	10	15	20	25	30	35	40
35			7,000				
40			9,600	12,400			
45			11,500	16,000			
50			15,000	19,500	25,300		
55			17,600	24,000	29,200		
60			22,700	28,500	35,400	42,100	
65			25,600	32,800	39,100	46,900	
70			30,500	39,100	46,300	54,300	
75			32,600	44,300	55,600	63,800	
80			39,440	49,700	60,800	69,600	83,200
85			43,600	56,100	68,300	82,300	94,400
90		34,500	46,300	58,100	70,100	84,250	96,200
95		39,130	53,220	66,540	78,800	92,300	106,200
100		43,500	57,700	74,000	89,300	103,900	123,000
110		53,500	71,300	89,000	107,700	123,800	142,300

Radius of Crane (Feet)	Crane Tracks Uncovered (Feet)						
	10	15	20	25	30	35	40
35			6,050				
40			6,850	8,875			
45			9,280	11,720			
50			11,200	14,000	17,600		
55			13,500	17,100	21,000		
60			15,900	20,400	25,100	29,600	
65			19,400	23,700	29,100	34,500	
70			22,300	29,600	34,200	39,300	
75			25,300	30,800	39,500	45,800	
80			30,100	37,600	45,200	53,600	61,500
85			34,400	41,900	50,700	60,500	71,100
90		31,200	41,500	52,100	60,800	70,800	80,600
95		32,900	43,860	54,500	63,000	72,100	82,500
100		36,200	47,000	60,000	69,000	79,100	90,600
110		45,500	60,100	74,000	85,000	94,800	106,500

In reclaiming, the crane delivers the coal upon the pile, *e*, which feeds into the boot, *g*. Thence by means of a gate and feeder the coal is delivered to the elevator, *h*, which in turn delivers it to the apron conveyor, *i*, which returns it to the screens and the spiralizers. If possible, coal of different sizes in storage is kept in separate piles, but if the plant is crowded all sizes are stocked together.

According to D. W. Buchanan, President of the Company, the cost of such a plant erected under war conditions would be approximately \$100,000. The expense of operation covering labor and supplies for stocking and reclaiming is about five cents per ton.

At the No. 8 mine of the same company, coal is stored by unloading cars with locomotive cranes upon piles parallel with the track and reclaiming it by means of the cranes.

At the mines of the Old Ben Corporation located in and near Christopher, a method of storage similar to that described as being in use at the Orient Mine of the Chicago, Wilmington and Franklin Coal Company (p. 51) has been established. This company has two mines at Christopher and two at Buckner. One mine of each pair has

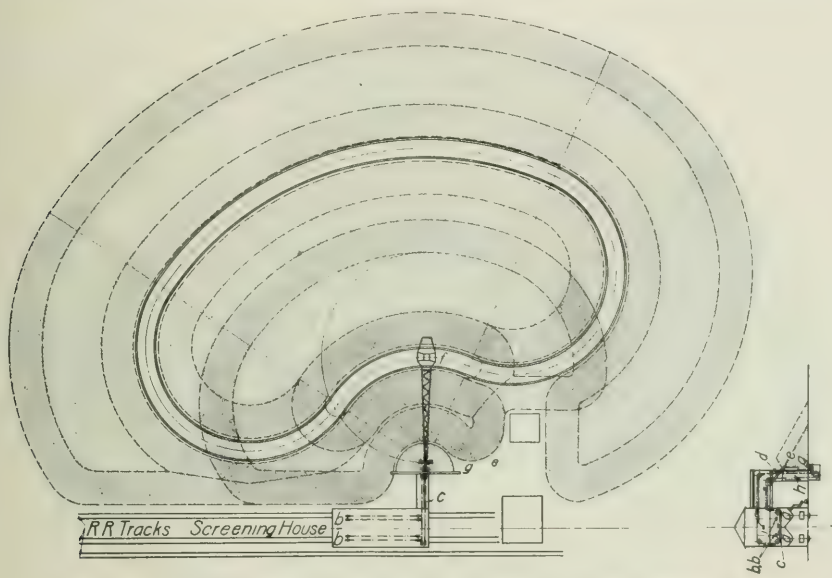


FIG. 26. ARRANGEMENT OF THE STORAGE PLANT OF THE OLD BEN COAL CORPORATION AT WEST FRANKFORT, ILLINOIS

been chosen as a storage point and the system of storage employing side dump cars and a locomotive crane has been established.

Many other adaptations of the semicircular or circular pile may be made, as, for instance, by placing the pile near a power house or a coaling station so that the crane in reclaiming can deposit the coal in a depressed hopper from which it is elevated into the power house, or coaling station (Fig. 27). For locomotive coaling the crane may deposit the coal into an overhead bin spanning the track as shown in Fig. 28.

According to the Storage of Coal Committee,*

* Proceedings, International Railway Fuel Association, Vol. VII, p. 159, 1915.

"The locomotive crane has been adopted by the Louisville & Nashville R. R., at three locations, where large mechanical coaling stations of reinforced concrete and steel construction have been erected (Fig. 29).

"The receiving hopper is enlarged at the back to form a pit of sufficient size to accommodate the grab bucket of the crane. The crane is located on a circular track back of this hopper, this track centering on the hopper. Coal is dumped into the hopper from the receiving track, and handled to storage by the crane. In reclaiming from the storage pile, coal is picked up by the crane and discharged into the hopper, from which it is handled to the overhead coal pocket in the usual manner.

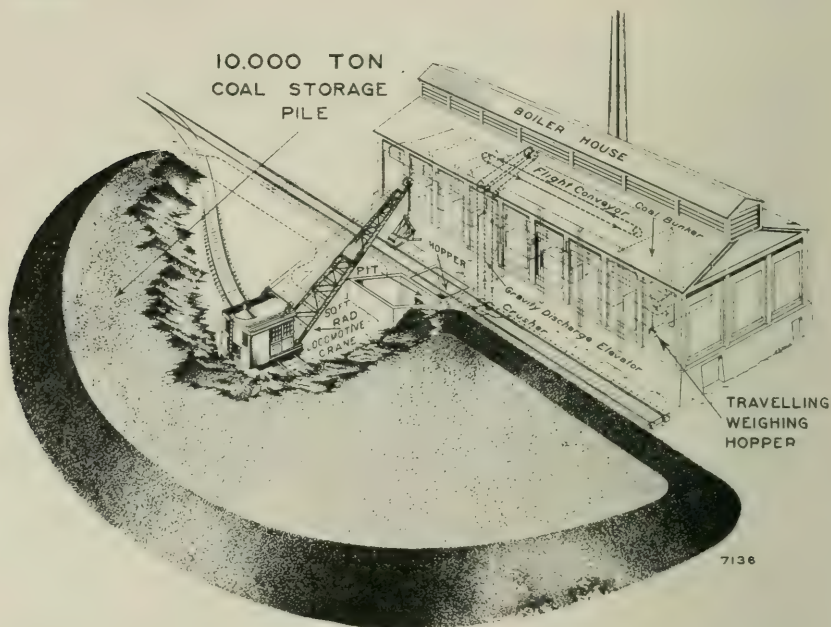


FIG. 27. SEMICIRCULAR STORAGE ADAPTED TO LOCATIONS NEAR POWER HOUSE OR COALING STATIONS

"A special crane of 110 feet radius is used by the Louisville & Nashville R. R., the crane track gage being 20 feet. In this way they secure a 22,000 ton storage with a 12-foot depth of pile. The crane uses a $3\frac{1}{2}$ -ton bucket, and has a working capacity of 150 tons per hour.

"An ordinary crane with a 40 or 60-foot boom could be used as well, but of course the size of storage pile would be reduced accordingly. The smaller crane would have some advantage in that it might be used for other purposes when not required to handle storage coal.

"For the most economical operation, such a crane should be electrically operated. Such a plant is estimated to cost \$23,000.00."



FIG. 28. LOCOMOTIVE CRANE RECLAIMING COAL AND DUMPING INTO BINS
ABOVE RAILROAD TRACKS

30. *Steeple Towers*.—Instead of a locomotive crane a steeple tower of steel or wood (Fig. 30) may be used. From such a tower a boom projects over the vessel or car into which the bucket is lowered. Upon being hoisted it is drawn back and dumped into a pocket from which the coal passes into a car, or is transferred by some other method to the point at which it is to be stored or used. These towers may be either fixed or movable. They usually run on tracks parallel with the water front. The booms are generally made so that they may be drawn back when not in use. With a $1\frac{1}{2}$ -ton bucket such a tower will unload and deliver to conveyors about 150 tons per hour.

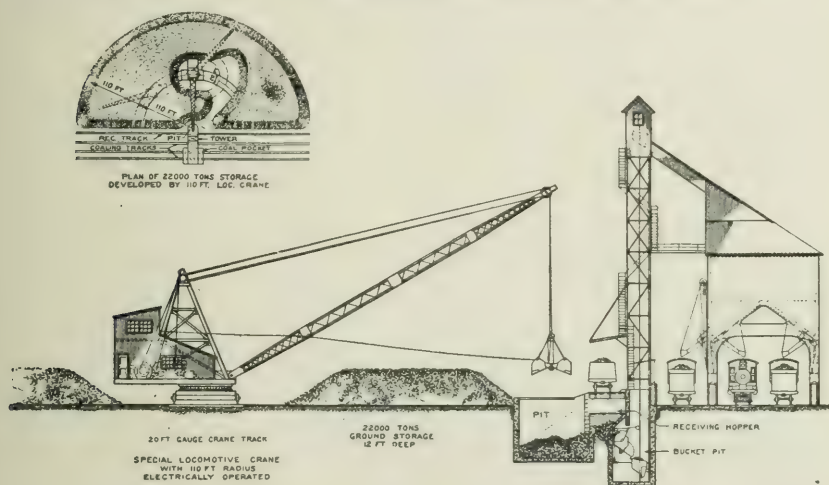


FIG. 29. L. & N. R. R. TYPE OF MECHANICAL COALING STATION
(Reprinted from Proceedings of the International Railway Fuel Association)

The storage yard of the Western Coal and Dock Company, Waukegan, Illinois, (Fig. 30) has three towers which deliver coal into cars running on a trestle about the storage yard.

By extending the boom backward through the tower, (Fig. 31) the buckets may be discharged into cars or upon a small stock pile. The tower may carry a self-contained hoisting unit or man trolley which moves along the boom and contains the drums and motors required to operate the bucket.

31. *The Hunt System*.—A common method of transferring coal to a pile is to dump it from a bucket into a bin from which it is discharged into a car which runs by gravity upon a trestle and as it

advances raises a counterweight. Such a system is illustrated by Fig. 32. The car is dumped automatically by a catch which may be set at any point along the trestle. As soon as the car is empty it is drawn back by the counterweight to its starting point and is then ready for another load. By means of a series of radiating trestles a large storage area may be reached by this system.

32. *Bridge Storage.*—A common form of transfer and storage is by means of a steel bridge which is usually movable about the storage yard and which serves as a support for a grab bucket, a belt, or other conveying devices. When both ends of the bridge are movable in a straight line, it becomes a gantry crane and may be made to cover any desired length of dock or storage yard, although because of the necessity for loading or unloading a cargo quickly these bridges do not generally travel over great distances. Fig. 33 shows a simple form of McMyler bridge gantry crane fitted with an electrically operated man trolley which serves a storage plant of about 50,000 tons.

A combination of unloading tower and traveling bridge utilizes to the fullest extent the ground area available, gives maximum storage, and usually provides maximum speed with minimum labor for both stocking and reclaiming. Steam or electricity is used for motive power, the choice being governed by the expense of operation.

Bridges may be divided into four classes according to the method of handling the coal on the bridge, as follows:—

(1) Rope trolley in which the bucket is operated from a stationary house on the bridge. Fig. 34 shows a bridge of this type built by Heyl and Patterson for the Reiss Coal Company at Superior, Wisconsin. The span of the bridge is 380 feet, the length of travel at present 1650 feet, and the storage capacity of the plant 450,000 to 600,000 tons.

(2) Man trolley in which the bucket is operated directly from a moving cab. Buckets holding from ten to twelve tons are used on this type of bridge. Fig. 35 shows two man trolley coal storage bridges built by the Wellman-Seaver-Morgan Company for the Indiana Steel Company, and equipped with 7½-ton buckets.

(3) Belt conveyor type in which the bridge serves as a support for a belt conveyor which, by means of an automatic trip, dumps the coal at any desired point.



FIG. 30. TOWERS EMPLOYED IN HANDLING COAL, WESTERN COAL AND DOCK COMPANY, WAUKEGAN, ILLINOIS

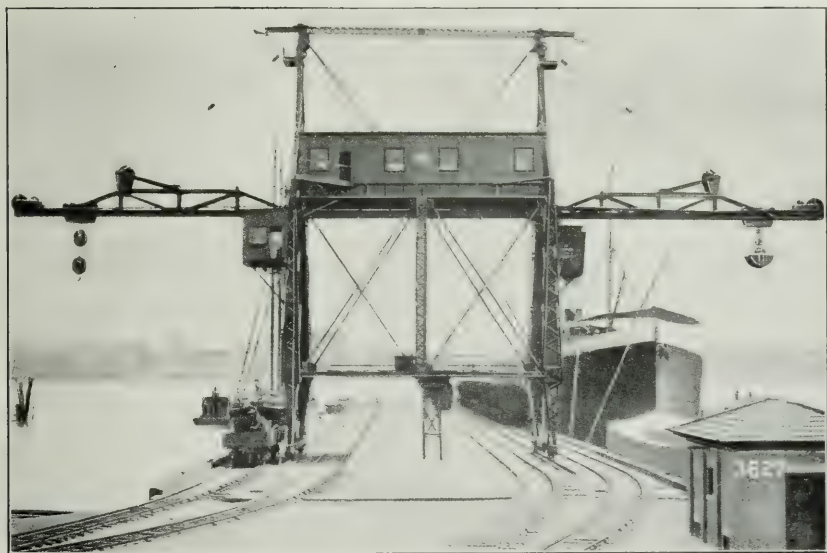


FIG. 31. TRAVELING TOWER OR DIRECT UNLOADER



FIG. 32. HUNT SYSTEM OF HANDLING COAL

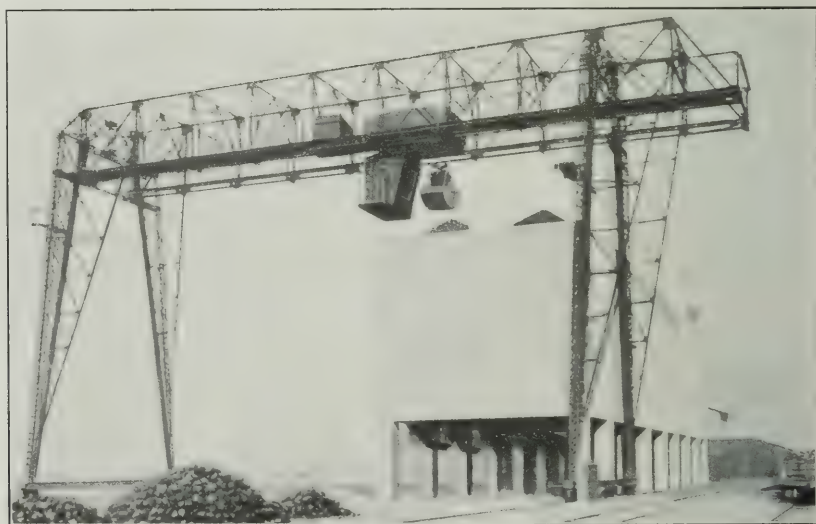


FIG. 33. BRIDGE GANTRY CRANE WITH ELECTRICALLY OPERATED MAN TROLLEY



FIG. 34. COAL HANDLING PLANT OF THE REISS COAL COMPANY AT
SUPERIOR, WISCONSIN

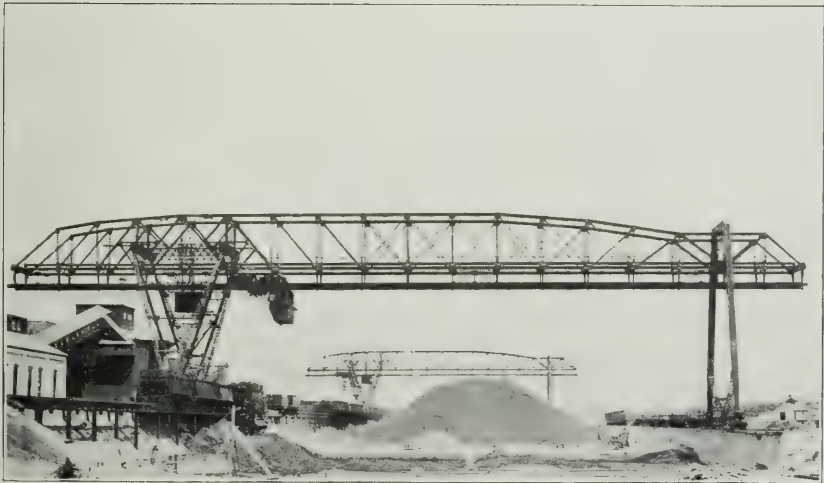


FIG. 35. MAN TROLLEY COAL STORAGE BRIDGES OF THE INDIANA STEEL COMPANY



FIG. 36. BELT CONVEYOR TYPE OF BRIDGE OF THE INLAND STEEL COMPANY



FIG. 37. MOVABLE BRIDGE WITH SIDE DUMP CARS

The belt conveyor type of bridge is illustrated by Fig. 36 which shows a large coal handling plant at the works of the Inland Steel Company at Indiana Harbor, Indiana, built by the Robins Conveying Belt Company.

(4) Cable road bridge on which a car runs. Fig. 37 shows a system in which the bridge moves over the length of the storage yard. Small side dump cars pass from a track running lengthwise of the storage yard upon the bridge from which they are dumped. The coal is reclaimed by a clam-shell bucket operated from the same bridge.

According to C. K. Baldwin* the capacity of storage bridges varies from 100 to 500 tons per hour, according to the size and speed of operation of the grab buckets or other carrying devices employed. The capacity of buckets varies from two to ten tons, the smaller sizes of from two to five tons being the more common. The span of the bridge usually depends upon the available storage space and may be as much as five hundred feet. The speed of the bridge varies from 50 to 200 feet per minute and that of the man trolley from 500 to 1500 feet per minute.

Fig. 38 shows a system of traveling bridges designed by Roberts and Schaefer Company, of Chicago, for the Clarkson Coal and Dock Company at Duluth, Minnesota. These bridges have a capacity of three hundred tons per hour from the vessel to the dock six hundred feet distant.

Fig. 39 shows a parallel track storage yard for a locomotive coal-ing station as suggested by the International Railway Fuel Association Committee†. The coal is unloaded and also reclaimed by means of a clam-shell bucket operated from a traveling bridge. The reloaded coal is delivered into a hopper at a stationary screening plant and elevated to the screens for preparation.

Fig. 40 shows the ground plan of a storage yard which is designed to handle as much as 20,000 tons of storage coal at a very low cost, by the use of a bridge and a traveling bucket. The coal is taken out of cars and placed in storage by means of the bucket, the labor being performed by the regular coal chute force during the dull seasons of the year, thus reducing greatly the expense of labor. The coal is recovered by picking it up with the bucket and delivering it to the con-

* Marks, L. S., "Mechanical Engineers' Handbook," p. 1131, 1916.

† Proceedings, Vol. VI, p. 115, 1914.

veyor chain which discharges it directly into the receiving hopper of the chute.

The following estimate for the expense of stocking with a bridge tramway is given by the Link-Belt Company (cost, interest, and depreciation not included) :

Labor and Supplies for stocking per ton	\$.041
Power and Superintendent's expenses	.014
Total	\$.055
Labor and Supplies for reclaiming per ton	.0385
Power and Superintendent's expenses per ton	.0130
Total	\$.0515

It is often desirable to screen the coal before it is reshipped from storage. The screening plant may be carried by the bridge, or it may be a separate movable structure. Fig. 41 shows a movable screening plant, built by the Link-Belt Company for the Berwind Coal Company, at Duluth, Minnesota.

A bridge is also applicable to storing in a circular pile. In such a case one end of the bridge is pivoted and the other end moves on a circular track about the pivot as a center. Instead of covering a complete circle this bridge may be used to cover any arc of a circle desired. A swivel bridge designed to operate in a semi-circle is shown by Fig. 42. Coal dumped into the pit at the side of the receiving hopper is picked up by the grab bucket on the bridge, and placed in storage. In reclaiming, the coal is picked up by the bucket, brought back to the receiving hopper, and elevated to an overhead storage bin.

This type of equipment is suited to a much larger storage pile and greater handling capacity than the locomotive crane, but is more expensive to operate.

The swivel bridge would probably be less economical than the locomotive crane for the handling of quantities within the capacity of the latter apparatus but can be advantageously employed for larger quantities. Coal may be handled at very little expense by a bridge where electric power is available.

The cost * of swivel bridges above the rails was given in 1915 as from \$25,000, for a bridge of 100-foot span, to \$50,000, for a bridge of 250-foot span; the capacities ranging from one hundred to three hundred tons of coal per hour.

* Proceedings, International Railway Fuel Association, Vol. VII, pp. 159-160, 1915.



FIG. 38. TRAVELING BRIDGES OF THE CLARKSON COAL AND DOCK COMPANY,
DULUTH, MINN.



FIG. 41. MOVABLE SCREENING PLANT OF BERWIND COAL COMPANY

Figs. 43 and 44 show a pivoted bridge built for the Milwaukee Coke and Gas Company by the Robins Conveying Belt Company. The semicircular concrete track on which the movable end runs has a 500-foot radius. The coal is elevated by an enclosed inclined belt conveyor which delivers it into a bin in the pivoted tower (Fig. 43). The coal is then put into storage by a belt conveyor, a tripper on the bridge depositing it at any desired point in the storage field. It is reclaimed by means of a six-ton bucket.

In order to get as much coal as possible under the bridge, a slightly inclined bulkhead, (Fig. 45) from twenty to twenty-five feet high, was built on both sides of the semicircular track and also around the outer edge of the pile. This bulkhead is made of boards and timbers projecting into the coal pile as shown in Fig. 46. When this method of bulkheading was first attempted there was a number of serious fires in the pile, probably caused by the circulation of slow currents of air through cracks between the planks. This difficulty has been overcome by studying the matter of sizes suited to storage and by closing the cracks, with reference to which J. F. Blackie, superintendent of the plant, says:

“It has been our experience that a coal from two inches up in size allowed a flow of air which cooled the pile rather than promoted combustion, and that fine coal prevented air circulation and did not, therefore, fire, but wherever the smaller lumps accumulated fires started. When all the cracks in the bulkhead were plastered with nine parts of coal dust and one part cement, fires were eliminated.”

The Milwaukee Coke and Gas Company has been storing each year for the past ten years 400,000 tons in one pile and 250,000 tons in another, the coal mixture consisting of 65 per cent West Virginia and Kentucky coals averaging 33 per cent volatile and 35 per cent Pocahontas averaging 18 per cent volatile. During the summer of 1917 it also stored Illinois coal in the same manner.

A method of unloading coal employed by the Canadian Pacific Railway at Fort William, Ontario, is illustrated by Fig. 47. The equipment consists of two Hulett unloaders with buckets of 8 tons capacity. The coal is rehandled from the stock pile under the unloaders by means of a large bridge, and stored in piles for future use. The bridge has a span of 285 feet with cantilevers approximately 150 feet long, is equipped with a man trolley which handles a nine-ton bucket, and is used both for stocking the coal and for reclaiming.

33. *Deep Reinforced Concrete Storage Bins.*—A storage plant of unusual design is that of F. W. Stock and Sons of Hillsdale, Michigan. It consists of reinforced concrete bins 28 feet in diameter and 70 feet deep built in pairs. Hopper bottom cars are unloaded through a track grating, the coal is carried by belt conveyor to a V-bucket elevator and dumped from the elevator head into the bins. A small pocket on the side opposite the elevator leg is used for anthracite coal for domestic use. The bins are roofed and the construction is such as to prevent the free circulation of air (Fig. 48).

As a precaution against fire each bin has six 1-inch pipes set vertically, each pipe being open at the top and having three or four side openings at intervals. These pipes are connected to a pressure water line so that it is possible to flood the bins if necessary to extinguish a fire. The bins are designed to withstand the pressure of coal having the interstices filled with water.

The estimated cost of the plant, complete with machinery, is \$18,000. The capacity is about 2000 tons. Records covering the expense of operation are not available, but the opinion is expressed that the expense will be less than that of open pile storage, even when the interest on the investment is included.

34. *Under-water Storage.*—Because of the liability to spontaneous combustion of coal storage piles exposed to the air, under-water storage has been used to some extent. Thus far this method has been applied exclusively to the storage of screenings.

The consensus of opinion is that coal stored under water deteriorates little, if any, in its chemical properties and in heat value. Professor Parr* says:

“Under-water storage prevents loss of heat value and is not accompanied by deterioration in physical properties such as slacking. The water retained by the coal upon removal is substantially only that held by adhesion or capillarity.”

This opinion is concurred in by a number of other writers,† and the opinions expressed in the questionnaire are unanimous upon this point.

At the present time there is a number of under-water storage plants and others are under consideration. The general adoption of

* “Effects of Storage upon the Properties of Coal.” Univ. of Ill. Eng. Exp. Sta., Bul. 97, p. 7, 1917.

† Hall, R. G., Mining and Scientific Press, March 15, 1913; Bennet, A., The Black Diamond, April 14, 1917; Palmerberg, W., Proceedings, International Railway Fuel Association, May, 1917.

under-water storage, however, seems to be influenced by the cost. One of the largest elements of cost is that of a suitable storage pit which may be an excavation made in solid ground, a dammed depression, an old quarry, or an abandoned clay pit. An abandoned quarry or clay pit has the advantage of saving the expense of excavation but there may be a considerable item of expense for cleaning out the old excavation. A quarry has solid but irregular walls, but if these are made even and the quarry cleaned out, it forms an ex-

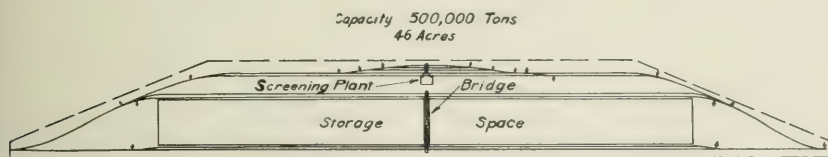


FIG. 39. PARALLEL TRACK STORAGE YARD FOR A LOCOMOTIVE COALING STATION
(Reprinted from the Proceedings of the International Railway Fuel Association)

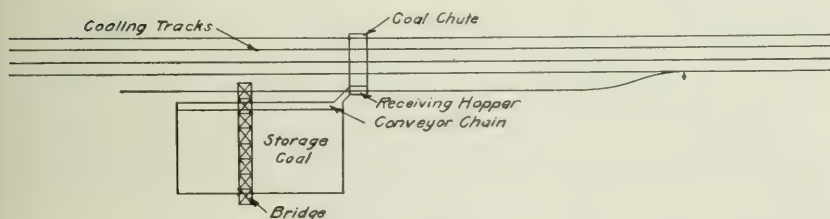


FIG. 40. LAYOUT OF STORAGE YARD FOR LOCOMOTIVE COAL STATION
(Reprinted from the Proceedings of the International Railway Fuel Association)

cellent place for storage. A clay pit has the disadvantage of soft walls, unless it is lined with timber or concrete. Several quarries have been used for storage purposes, and apparently with success. These old quarries are frequently fed by springs, so that the water supply is assured but is generally not sufficient to cause an overflow. One of the latest plants has utilized a pit excavated in an old slough which has been dredged out. In this case the cost of excavation was low and a permanent water supply assured. One drawback to under-water storage lies in the freezing of the water during winter, or if the surface does not freeze the wet coal may freeze while handling. So far as reported, however, freezing has not been found troublesome.

in the vicinity of Chicago and other Middle West cities near which many of the under-water storage plants are located.

A pioneer in under-water storage was the Western Electric Company, Chicago, Illinois. This company, after a number of fires in its bunkers at the Clinton Street plant, built in 1902 a concrete pit with a capacity of 3000 tons. It was not water-proof, but the water level in the pit was maintained by an intake from the Chicago River. Coal was stored in this pit during the winter months and used during the early summer without appreciable loss in weight or trouble in burning the coal.

In connection with its extensive new plant at Hawthorne, Illinois, the Western Electric Company in 1906 provided a concrete-lined pit having a capacity of 10,000 tons. This pit, shown in Figs. 49 and 50, occupies a ground area of 310 by 114 feet, and is divided into three parallel sections by concrete arch partitions. It is about fifteen feet deep, and the bottom is inclined since rock was encountered in sinking the pit. Water is provided from the roofs of the adjacent factory buildings. Three railroad tracks are carried on the arched piers and extend the entire length of the pit, and there are two railroad tracks on each side. Coal is unloaded into the pit by hand at an expense of five cents per ton. A locomotive crane with a grab bucket reclaims and reloads the coal at an expense of about four cents per ton. Loaded cars stand on the tracks from twenty-four to forty-eight hours to allow the water to drain off into the pit. Illinois screenings of one inch or one and one-half inch size are stored.

According to *The Colliery Engineer*,* the original construction cost of a pit of this description was about \$7,000, for each thousand tons capacity. Later, when the company considered extending the plant by building a pit which would hold about 22,000 tons, the cost of the extension was found to be about \$60,000, including the crane and necessary railroad tracks.

Another pioneer in under-water storage is the Illinois Traction Company which has two plants, one at Riverton and another at Mackinaw.† The one at Riverton holds approximately 9,000 tons and the one at Mackinaw approximately 16,000 tons. The construction of these pits is shown in Fig. 51. The floor of the pit illustrated is 275 feet by 80 feet and the tank is 319 feet by 128 feet.

* January, 1915.

† Detailed descriptions of these plants will be found in *Electric Railway Journal*, April 1, 1911, and *The Colliery Engineer*, January, 1915.

The water is pumped from the Sangamon River by a motor-driven centrifugal pump, and the water in the pit may be drained out when desired through a ten-inch valve. The center trestle is of yellow pine twenty-four feet high, extends the full length of the pit, and rests on concrete with steel rail reinforcing. The floor between the trestle bents is also reinforced with rails placed four feet apart. The Riverton pit, similar in construction, is twenty feet deep, the bottom being 80 feet by 185 feet and the top 124 feet by 225 feet. The concrete bottom has triangular mesh reinforcement instead of rails and underneath it are concrete foundations for the bents. The con-

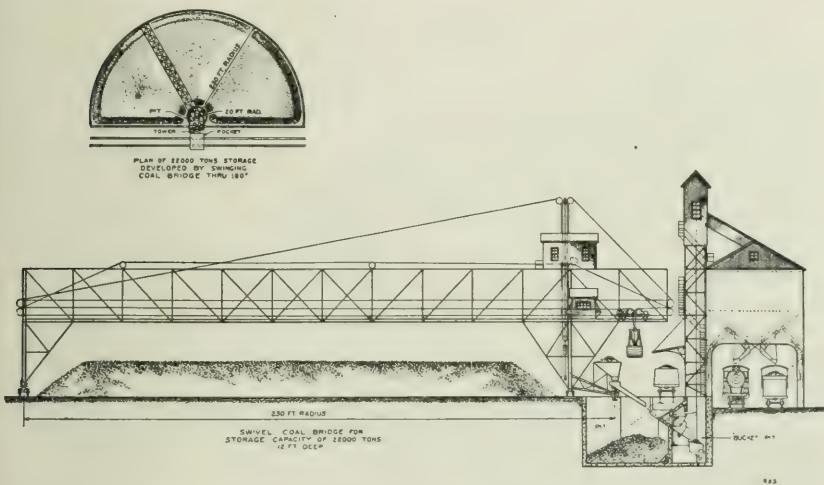


FIG. 42. SWIVEL BRIDGE DESIGNED FOR SEMICIRCULAR PILE

(Reprinted from the Proceedings of the International Railway Fuel Association)

crete has a one-inch wearing surface, two per cent of which is a water-proofing compound. R. J. Carley, chief operating engineer of the Illinois Traction System, reported in 1913 that little trouble was experienced in holding the water in the Riverton pit and that there was little deterioration of the coal. There was considerable trouble in holding the water in the pit at Mackinaw, and coal in storage there for one period of about eighteen months slacked considerably because of the lack of water. The difference in tightness was thought to be due to the better water-proofing at the Riverton pit. The Mackinaw pit required a small amount of excavation and cost \$14,300 or about \$900 per 1000-ton capacity. The Riverton pit cost \$11,000 or about

\$1,225 per 1000 tons. The Riverton pit was situated so that it was necessary to build only earth embankments to hold the concrete retaining walls.

The Illinois Traction Company stores coal of all sizes from the Worden district, Illinois, and keeps it in storage for from six months to three years. There is no appreciable loss in heat value, and there is no appreciable breakage. The total expense of operating these plants is 14.6 cents per ton for storing and 7.8 cents for reclaiming. The Company also stores coal upon the ground in continuous piles fifteen feet deep and in case of heating removes the coal from the affected spot.

The American Zinc Company of Illinois stores 35,000 tons in a lake at its Hillsboro plant, the coal being dropped into the water through a plate girder bridge, and reclaimed by a centrifugal pump which delivers it into a dewatering elevator. The coal keeps in excellent condition under water and contains practically no more moisture when reclaimed than when freshly mined. The company also carries a stock of from thirty to forty cars of coal which lies on the ground for not more than thirty days. According to A. Ives, Superintendent, coal stored in the open deteriorates so rapidly that it is almost useless for gas making.

The East St. Louis Light and Power Company cleaned out an old rock quarry adjacent to its power station in which about 7,000 tons of coal are stored under water. This plant has been operating satisfactorily except for some slight difficulty due to freezing in the winter. There is also some difficulty due to freezing in the bunkers.

The National Zinc Company of Springfield, Illinois, utilizes an old clay pit about 250 feet wide, 450 feet long, and 45 feet deep which has a capacity of about 30 car loads.* This pit formed a natural sink in the surrounding prairie, and was, therefore, usually filled with water to a point about five feet from the top. The sides and bottom are of comparatively hard shale. A railroad track parallels the longer side. The track is carried on a low trestle over an unloading chute, sufficiently wide to accommodate one car. The bottom of the chute has a slope of ten per cent toward the pond, and the outlet into the pond is about four feet wide. At the top end of the chute is a ten-inch pipe having four-inch holes in the side. This pipe is attached to a ten-inch centrifugal pump which delivers about 3,500

* Detailed description of this plant will be found in *Mining and Scientific Press*, p. 406, March 15, 1913 and in *The Colliery Engineer*, p. 299, January, 1915.

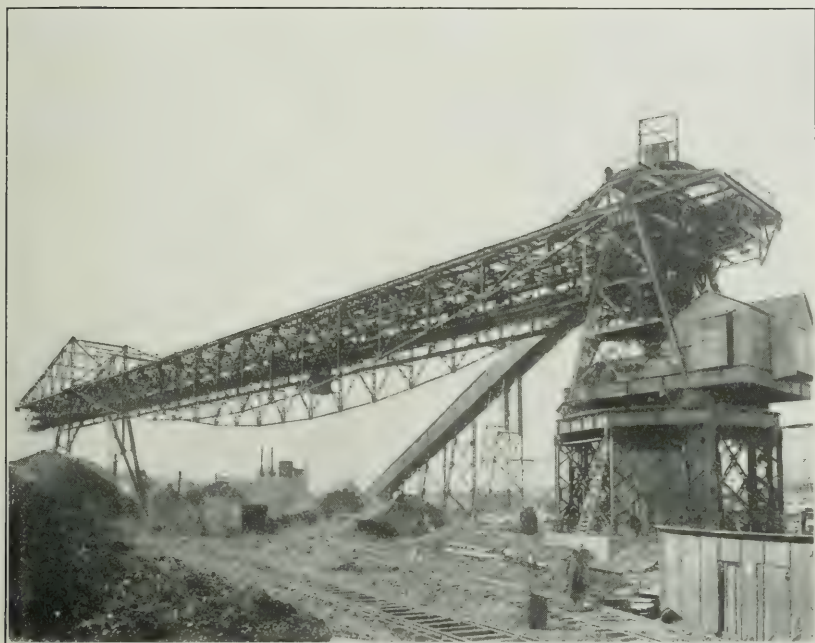


FIG. 43. PIVOTED BRIDGE OF THE MILWAUKEE COKE AND GAS COMPANY

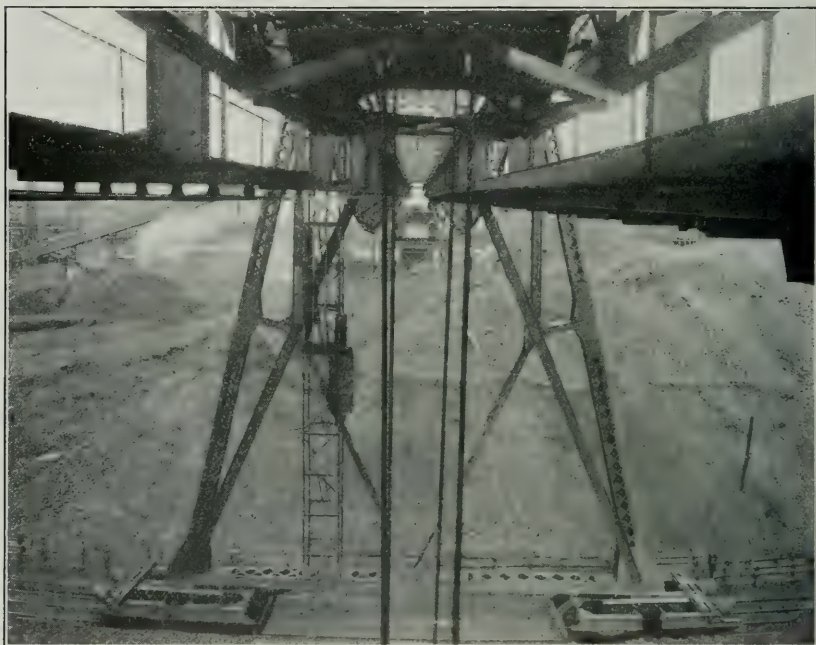


FIG. 44. VIEW LOOKING TOWARD PIVOTED END, BRIDGE OF THE MILWAUKEE
COKE AND GAS COMPANY



FIG. 45. BULKHEAD AT THE STORAGE PLANT OF THE MILWAUKEE COKE AND GAS COMPANY



FIG. 46. VIEW SHOWING CONSTRUCTION OF THE BULKHEAD AT THE PLANT OF THE MILWAUKEE COKE AND GAS COMPANY

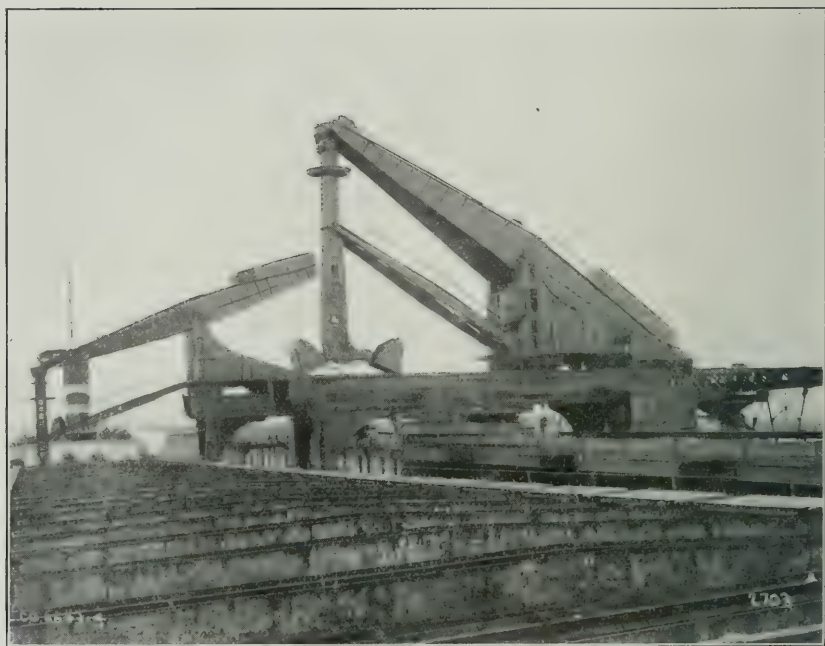


FIG. 47. HULETT UNLOADERS OF THE CANADIAN PACIFIC RAILWAY AT
FORT WILLIAM, ONTARIO



FIG. 48. REINFORCED CONCRETE STORAGE BINS OF F. W. STOCK AND SONS,
HILLSDALE, MICHIGAN, DESIGNED AND BUILT BY MACDONALD ENGINEERING
COMPANY, CHICAGO

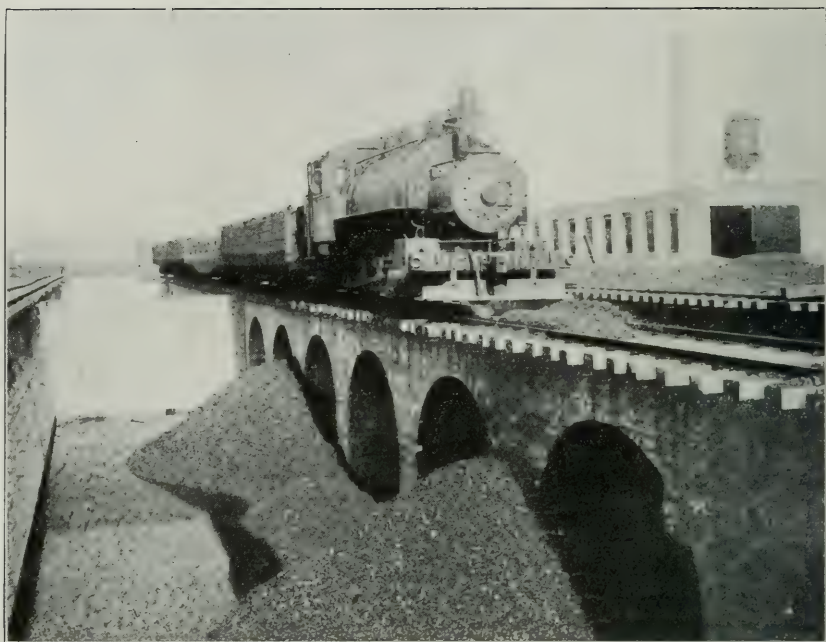


FIG. 49. VIEW OF THE UNDER-WATER STORAGE PIT OF THE WESTERN ELECTRIC COMPANY AT HAWTHORNE, ILLINOIS



FIG. 50. VIEW OF THE UNDER-WATER STORAGE PIT OF THE WESTERN ELECTRIC COMPANY AT HAWTHORNE, ILLINOIS



FIG. 52. STORAGE PIT OF THE NEW KENTUCKY COAL COMPANY, KANKAKEE,
ILLINOIS



FIG. 53. CONCRETE STORAGE PIT OF THE INDIANAPOLIS LIGHT AND HEAT
COMPANY



FIG. 54. STORAGE PIT OF THE METROPOLITAN WATER DISTRICT OF OMAHA

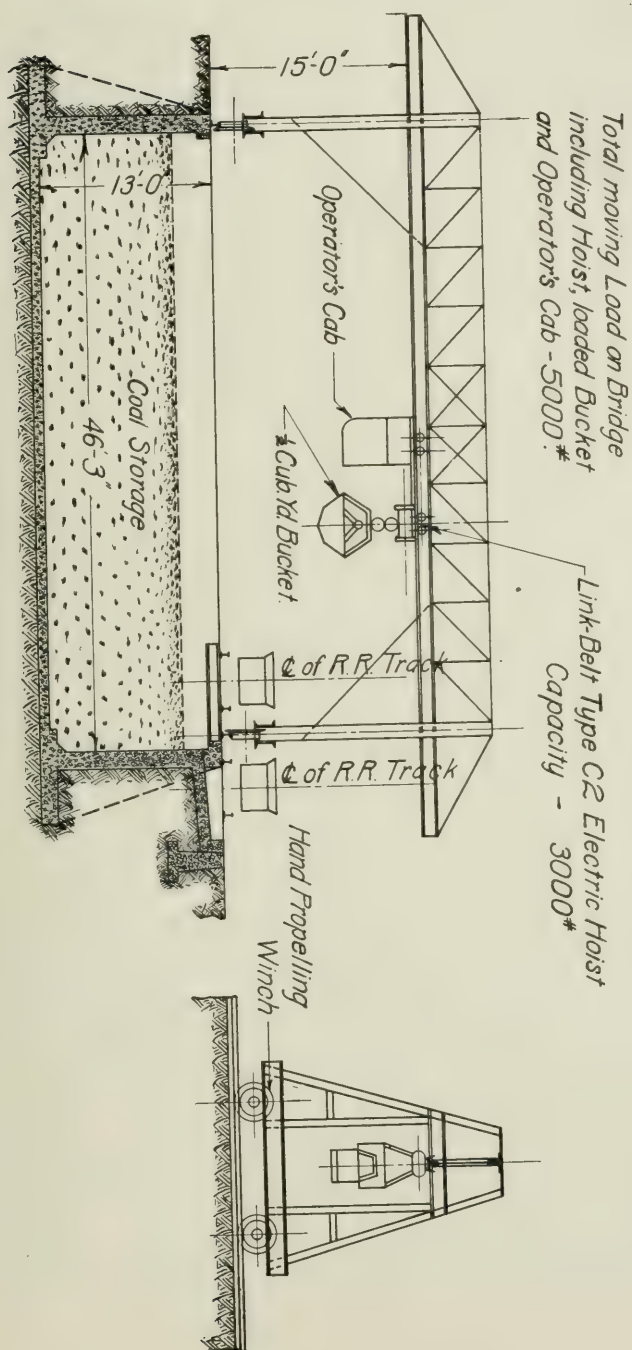


FIG. 55. STORAGE PIT AND BRIDGE OF THE WESTERN CLOCK WORKS

gallons per minute. When a loaded car is placed on the trestle, two men open the drops, section by section. This action throws most of the coal into the chute, and the water backs into the chute until the accumulation is sufficient to move the whole mass of material. When the bulk of the material has moved out, the men close a valve in the pipe to the chute, and throw the whole stream of water directly into the car to clear it. The whole operation of unloading a car requires on the average about ten minutes.

In reloading, the coal and water are pumped directly into the elevator boot which is placed in a hopper-shaped hole excavated in the ground and lined with plank, and the water is forced to travel slowly around the hopper before finding its way back into the pond.

The coal pump is placed on a barge 15 feet by 40 feet and is belted to a 50-horse-power motor. Both the suction and discharge are light spiral riveted iron pipes, which though short lived provide ease of its manipulation. The discharge pipe is carried on pontoons made from oil barrels. One operator on the barge finds no difficulty in moving the pipe around as the ground is worked out.

J. Kaercher, of the National Zinc Company, reports that the expense of storing at present is ten cents per ton and the expense of reclaiming ten cents per ton. The coal is kept in storage indefinitely and different sizes are stored without being separated. The coal stored is to be used for the production of producer-gas, and there has been no appreciable deterioration.

The New Kentucky Coal Company at Kankakee, Illinois, has a complete under-water storage plant, built according to the plans of Mr. Harwood, its vice-president and general manager. An old limestone quarry was utilized as the storage pit, the water being supplied from springs which keep the quarry full. The shape of the basin is elliptical, being about 700 feet long, 310 feet wide, and 30 feet deep. Since the rock was channeled, the sides are in excellent shape and are regular. A view of this pit is shown as Fig. 52. Water obtained from pipes along the track is used to flush the coal out of the cars and down the chute into the pond. As the coal piles up around the bottom of the chute, it is pumped out into the quarry by means of a ten-inch centrifugal pump operated by a 75-horse-power motor, the pump and the motor being mounted on a barge. The pipe line consists of a sectional pipe, ten inches in diameter, which rests on pontoons.

To reclaim the coal the process is reversed and the coal is pumped from the quarry into the concrete pit at the base of the inclined elevator. When this pit is filled with coal, the water overflows back into the quarry. Coal from the pit is elevated by a flight conveyor of perforated buckets through which much of the water drains and is delivered into cars on the railroad track. In the small house at the left of the elevator (Fig. 52) is a six-inch centrifugal pump operated by a 25-horse-power motor which pumps the water needed for flushing the coal from the cars and down the chutes. The storage capacity is estimated to be from 200,000 to 250,000 tons of coal and it is stated that about 2,000 tons per 8-hour day can be unloaded and 1500 tons reclaimed. Coal of sizes under three inches can be handled by the equipment. Unfortunately, the plant has not been operated owing to lack of coal supply. Three men are required to operate the plant and the cost is estimated to be from seven to ten cents per ton for unloading and reclaiming. The equipment cost about \$20,000, including the switch track and trestle, but at the present time the same equipment would cost from \$28,000 to \$30,000.

The Indianapolis Light and Heat Company (T. H. Wynne, Superintendent of Power)* stores 20,000 tons of Indiana run of mine coal from the Linton district under water in concrete tanks twenty-four feet deep (Fig. 53). The coal is dumped directly from railroad cars and is reclaimed by a locomotive crane. A deterioration of less than three per cent in heating value is said to take place. The stored coal is used after the first of January, when the price of coal is, normally, highest, and the pit is refilled during March, April, and May.

The Metropolitan Water District of Omaha, Nebraska, stores for steam purposes 4,000 tons of Iowa, Kansas, and Illinois coals. Most of this is slack below three-fourths inches, although some nut and washed coal is used. The storage pit (Fig. 54) is of concrete ten feet deep. The period of storage is about six months. The coal is piled from fifteen to twenty feet above the water in order to get an additional storage. This coal may heat in from three days to two months and if so it is then turned over by means of a locomotive crane which is used to stock and unload the coal from the bins.

*See *Electrical World*, Vol. 62, p. 592, Sept. 20, 1913, *Electric Railway Journal*, Vol. 42, p. 391, Sept. 6, 1913, *Engineering News*, Vol. 70, p. 527, Sept. 1, 1913, *Power*, Vol. 38, p. 485, Sept. 30, 1913.

The expense of this storage is given as follows:

	Storing	Reclaiming
Overhead	\$0.003	\$0.003
Labor	.012	.012
Supplies	.005	.005
Depreciation on mechanical equipment	.024	.024
Interest on investment	.019	.019
Total	\$0.063	\$0.063

The Company also stores some coal on the ground, but because of fires is now planning to store 30,000 additional tons in abandoned concreted water basins, utilizing a hydraulic ejector similar to those used for years in transporting sand through a pipe for filtration purposes. G. T. Prince, Chief Engineer, says:

“Any coal stored in the air, whether supported by coal in a pit under water or by planking on the ground is subject to spontaneous combustion. This is particularly true of coal received in a damp, wet state. When such coal reaches us we exercise great care in watching it, as it is sure to catch fire within a few weeks and possibly within a few days. Coal received during the dry summer days will be free from combustion for several months.”

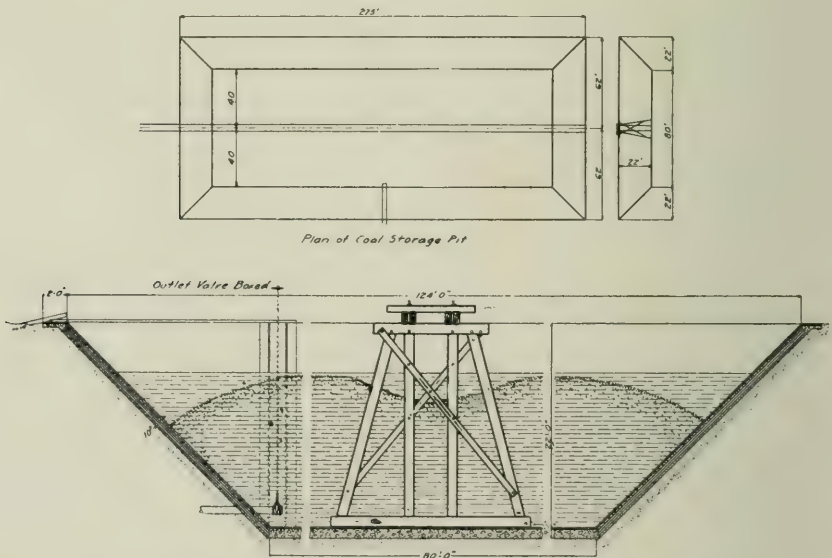


FIG. 51. COAL STORAGE PIT OF THE ILLINOIS TRACTION COMPANY AT MACKINAW, ILLINOIS

Fig. 55 shows a cross-section of a storage pit recently built by the Western Clock Works in Peru, Illinois. The pit is 87 feet long, 46 feet, 3 inches wide, and 13 feet deep and has a capacity of 1200 tons under water. The cost of the plant was \$15,300. The coal stored comes from a mine, about two hundred feet distant. The traveling bridge and bucket are used to distribute the coal in the pit and to reclaim it. The reclaimed coal is placed in the small cars on alternate days, the cars being allowed to drain for a day before the coal is delivered to the boiler room.

One of the largest under-water storage plants now under construction is being built by the Great Lakes Dredge and Dock Company for the Standard Oil Company of Indiana at Whiting, Indiana. The pit will be 1000 feet long, 202 feet wide below the ground water level, and 26 feet below the yard rail level. The system is to be practically the same as that of the Western Electric Company at its Hawthorne plant but instead of the heavy concrete construction for walls and trestles, wood piles will be used below water level and will be capped with a coping of concrete above water level. The bottom of the pit will be roughly graded and lined with concrete one foot thick. The only part of the construction which will be subject to deterioration will be the ties, stringers, and caps of the railroad trestle which are above water.

Four trestles, on which will be a standard gage track, will extend from end to end of the pit. Alongside the pit will be two railroad tracks, so that locomotive cranes to be used for reclaiming may operate from the trestles above the pit or from the side tracks. It is estimated that the cost of construction will be much less than that of the concrete types used in other plants. By means of the four tracks placed on the trestles and the two on the sides, six trains may be unloaded at one time.

The Peabody Coal Company of Chicago has three under-water storage plants, one holding about 80,000 tons at Kankakee, one holding 60,000 tons at Lemont, and another at Momence, Illinois. The one at Momence, however, has not been placed in operation. In each case an old quarry has been used. The coal is dumped into the quarry from a track running near the edge and distributed by means of a centrifugal pump. In reclaiming, the coal is pumped into an elevator and delivered directly into railroad cars. The Company reports that where the pile of coal projected above the water level along the bank it took fire.

An estimate given by the engineers of the Peabody Company for the cost of equipment and the expense of operation of the Lemont plant is as follows:

ESTIMATED COST OF EQUIPMENT AT LEMONT STORAGE

(BASED UPON HANDLING 700 TONS OF COAL PER DAY—ALLOWANCE MADE FOR STOPPAGE AND BREAKDOWNS)

Shooting rock and building unloading chute	\$350.00
Building concrete piers, laying stringers, and installing track	780.00
Rearrangement of track to get greater capacity	800.00
12-inch centrifugal pump, directly connected to 100-horse-power steam engine	2250.00
Boat to float pump and engine	600.00
300-foot spiral riveted pipe with bolts and gaskets	800.00
2- to 5-foot sections of rough bore suction and	
2- to 5-foot sections of smooth bore discharge hose	800.00
125-horse-power self-continued steam boilers	1000.00
Priming pump, connected to pump engine, 12-inch check valve	125.00
Steam injector, boiler fittings, etc.	225.00
100 feet of 3-inch steam pipe and 3-to 5-foot sections of 3-inch steam hose	110.00
Elevator of dewatering type, to elevate 120 tons of coal per hour at a speed of 50 feet per minute, connected to steam engine	2000.00
Wood receiving boat at foot elevator 20 by 20 by 8 feet, also wood support and erection of elevator	700.00
Self-contained car puller and engine with 1500 feet of ½-inch steel cable, with head sheaves, etc.	650.00
Ropes, blocks, bars, etc.	200.00
10 per cent for supervision	1140.00
Total	<u>\$12,530.00</u>

To clean quarry:

Pumping dry, removing debris from bottom, and additional expenditure estimated	\$1500.00
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ESTIMATED EXPENSE OF OPERATION AT LEMONT STORAGE
(BASED UPON HANDLING 700 TONS OF COAL PER TEN-HOUR DAY)

Unloading	Per Day	Expense Per Ton
Superintendent (1)	\$5.50	
Pumpman (1)	3.50	
Carpuller (1)	3.00	
Dumpers and Pipemen (2)	6.00	
Fuel for boilers and lubricating oil	6.00	
Miscellaneous repairs and supplies	2.50	
Night Watchman (1)	3.00	
Total	\$29.50	\$0.042

Reloading		
Superintendent (1)	\$5.50	
Pumpman and Helper (1)	6.50	
Pipeman (2)	6.00	
Trimmer (1)	3.00	
Carpuller (1)	3.00	
Fuel for boiler, oil, etc.	6.00	
Miscellaneous supplies and repairs	2.00	
Night Watchman and Trimmer (1)	3.00	
Total	\$35.00	\$0.0500

6 per cent per annum on investment*	
\$15,000 spread over 60,000 tons = \$900*	0.0150
Unforeseen delays, etc.*	0.0100
Losses one per cent on 600 tons at \$1.50	
per ton = \$900*	0.0150
Depreciation on equipment*	0.0200
Accident insurance, etc.*	0.0100
Total Expense of Storing	\$0.1620

If electric power is used, the cost will be five cents per ton higher.

The following are comparative estimates of the expense of under-water and surface storage made by C. G. Hall, formerly fuel agent of the C. & E. I. Railroad.

* Losses at one per cent are estimated upon the basis of operation over a period of years. The interest, delays, depreciation, and similar expenses are based upon loading and unloading 60,000 tons per annum. A smaller tonnage will materially increase these items of expense.

STORAGE OF SCREENINGS (INDIANA COALS)

Subaqueous Storage (3rd,

5th, and 6th vein coal)	100,000 Tons	
Pump outfit	\$12,000.00	
Interest and depreciation	20 per cent	\$2,400.00
Tracks (estimated)	2,000.00	
Interest and depreciation	15 per cent	300.00
Labor, supplies and power, Unloading and reloading		10,000.00
Rental of storage pit		250.00
Value of 100,000 tons at 50 cents per ton and freight charges at 82 cents	\$132,000.00	
Interest on \$132,000.00 at 6 per cent for 8 months		5,280.00
		\$18,230.00
Average per ton		18.23 cents

Surface Storage (4th Vein Coal) 25,000 Tons

Locomotive crane	\$8,000.00	
Interest and depreciation	20 per cent	\$1,600.00
Tracks	5,000.00	
Interest and depreciation	15 per cent	750.00
Labor and supplies, Unloading and reloading		2,500.00
Rental of ground, etc.		200.00
Value of 25,000 tons at 75 cents per ton and freight charges at 77 cents per ton	\$38,000.00	
Interest on \$38,000.00 for 8 months at 6 per cent		1,520.00
		\$6,570.00
Average per ton on 25,000 tons		26.28 cents

VI. EFFECTS OF STORAGE UPON THE PROPERTIES OF COAL

The effects upon the properties of coal may be considered under the following heads:

- (1) Appearance.
- (2) Loss of heating value.
- (3) Firing qualities.
- (4) Spontaneous combustion.
- (5) Coking and gas making properties.
- (6) Degradation, or the increase in the amount of fine coal and dust due to breakage from handling, and to slacking or weathering.
- (7) Loss in weight.

35. *Appearance*.—Many coals upon exposure to the air become covered with a coating of white iron sulphate which causes a pile to look as though covered with frost. This white coating is thought by many to signify deterioration of the coal, but as shown by Professor Parr it merely signifies that some of the sulphur has oxidized to the white sulphate, which is soluble in water, and is easily washed away by rain. The ash content of such coal is also slightly lower than that of fresh coal. In any case, the white coating is only a covering, and the coal below the surface of the pile is not affected.

36. *Loss of Heating Value*.—The loss of heating value resulting from storage is comparatively small and Parr* says with regard to this: "Bituminous coal can be stocked without appreciable loss of heat values provided the temperature is not allowed to rise above 180 degrees F. In fact, there is no appreciable evolution of CO_2 at temperatures below 260 degrees F. The indicated heat loss per pound of coal is due more largely to an increase in weight of a unit mass of coal resulting from the absorption of oxygen rather than from an actual deterioration or loss of heat units. . . . Under-water storage prevents loss of heat value." According to detailed values given by Parr† and summarized in Table 5, the indicated loss of heating value

* "Effects of Storage Upon the Properties of Coal." Univ. of Ill. Eng. Exp. Sta., Bul. 97, pp. 7, 38, 1917.

† Ibid., pp. 15-22.

TABLE 5
DECREASE IN HEATING VALUE (B. t. u.) OF ILLINOIS COALS

Coal Tested and Length of Time Stored	Nut		Screenings		Nut	Screenings
	Exposed Bins	Covered Bins	Exposed Bins	Covered Bins	Under- water	Under- water
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
<i>Stored 1 year</i>						
Williamson County.....	0.84	1.64	1.37	1.35	0.93	0.57
Vermilion County.....	2.13	2.77	3.92	4.46	2.00	2.72
Sangamon County.....	3.15	4.12	5.14	4.52	1.83	0.86
<i>Stored 3 years</i>						
Williamson County.....	2.09	3.60	2.11	3.73	....	....
Vermilion County.....	4.98	6.23	8.48	10.47	....	....
Sangamon County.....	4.54	....	7.11	10.48	....	....
<i>Stored 6 years</i>						
Williamson County.....	3.04	3.60	3.96	4.31	....	....
Vermilion County.....	5.49	6.39	10.83	....	....	....
Sangamon County.....	6.49	6.81	6.85	10.81	....	....

after a period of one year in storage is relatively low, averaging for nut coals and screenings from Williamson, Sangamon, and Vermilion counties only about 3 or 3½ per cent. Coals vary in this respect, those from southern Illinois showing less change than those from central Illinois and this difference increases with the length of time in storage, that is, the coals which show a small decrease in heating value at first continue to show a relatively small decrease as time goes on.

Decrease in heating value is consistently greater with screenings than with screened nut, according to Parr's tests of Illinois coals.

Coal stored in open bins shows consistently a lower percentage of loss of heating value than coal stored under cover, due no doubt to the oxidation of the sulphur when exposed to the air and its subsequent leaching out.

Experiments made by the Bureau of Mines upon large samples of coal gave the following results:*

"The amount of deterioration of coal in heating value during storage has commonly been overestimated. Except for the subbituminous Wyoming coal, no loss was observed in outdoor weathering greater than 1.2 per cent in the first year, or 2.1 per cent in two years. The Wyoming coal suffered somewhat more loss; 2 to 3 per cent in the first year and as much as 5.5 per cent in three years."

* Porter, H. C., and Ovitz, F. K., "Deterioration in the Heating Value of Coal During Storage." U. S. Bureau of Mines, Bul. 136, p. 8, 1917.

New River coal tested at Portsmouth, N. H., Pittsburgh, Pa., and Norfolk, Va., gave the following results:

"In general, the conclusion to be drawn from these tests is that New River coal, under severe conditions of outdoor exposure to the weather, deteriorates in heating value approximately one per cent in the first year, two per cent in the first two years, and not over three per cent in five years. Storage under water prevents practically all deterioration during one year, and no more than 0.5 per cent has been found in any test for two years or less. Salt water possesses no advantage over fresh water in preventing deterioration. Intermittent exposure and partial drying of the submerged coal probably causes deterioration in some degree, although very small.

"Submergence storage of New River coal is not to be recommended for the sake of preventing deterioration in heat value. Its advantage lies only in insuring against spontaneous combustion."*

Tests of Pittsburgh coal at Ann Arbor, Mich., gave the following results:

"The amount of deterioration in one year's open air storage was practically negligible, even in the upper six inches of the exposed coal. During the second, third, fourth, and fifth years the deterioration proceeded very slowly and did not reach an amount greater than 1.1 per cent in five years. The submerged portions may be said to have suffered practically no loss measurable by the degree of accuracy used."†

Pocahontas coal tested on the Isthmus of Panama gave the following results:

"During one year's outdoor exposure this coal deteriorated very slightly (less than 0.4 per cent) in heating value, and that the deterioration took place entirely during the first months (June 15 to December 15). There was a further deterioration of 0.4 per cent during the second year."‡

Sheridan, Wyoming, lignitic coal stored at Sheridan gave the following results:

"Coal under the conditions of these tests loses 3 to 5.5 per cent of its heat value in about three years' storage, the greater part (70 to 80 per cent) of this loss being in the first nine months. During the period of $2\frac{3}{4}$ years, the deep bins suffered the greatest loss, probably because their sides offered greater surface for access of air than those of the small bins. The latter became covered with a 12-inch layer of fine slack that helped to protect the layers beneath from oxidation. In the deep bins, the lumps became badly cracked, but retained their form sufficiently to give more ready access of air, and thus permit greater oxidation.

"In storage of Sheridan coal for more than three months, covering the bins is

* Ibid., p. 22.

† Ibid., p. 25.

‡ Ibid., p. 29.

not as advantageous as the use of air-tight bottoms and sides (of concrete, for example), and the accumulation of a protecting layer of fine slack on the surface. The deterioration of Sheridan coal in heat value can probably in this manner be kept below three per cent in one year, and will probably not increase to more than four per cent in two or three years if the coal remains undisturbed. Physical deterioration (slacking) is also largely prevented in the under portions by the formation of a closely packed layer of slack, at least twelve inches thick on the surface.

“Although no indications of spontaneous heating were noted in the tests herein described, it is found in practice to be dangerous, on account of dangerous heating, to store Sheridan coal in piles greater than about ten feet in depth or width. In large masses of coal radiation of spontaneously developed heat is restricted to a dangerous degree. Submerged under water would probably prove particularly advantageous as a means of safely storing subbituminous coal of the Sheridan type”*

The Coal Storage Committee of the International Railway Fuel Association in 1915 reported that for Ohio, Pennsylvania, and West Virginia the loss was very slight and that no difference was noted by customers of a large coal company between the fresh coal and coal stored from six to twelve months.

The Boston and Main Railroad has had coal in storage from fifteen to twenty years with no signs of heating, and although there was surface deterioration, lumps were found within the pile which looked like freshly mined coal and showed a heat value of 13,000 B. t. u.

Kansas coal showed a shrinkage of 5.26 per cent in weight due no doubt to drying out.

Oklahoma, Kansas, Missouri, and Northern Arkansas coals lose from two to eight per cent in heating value and Texas coals much more due to spontaneous combustion.

J. G. Crawford, Fuel Engineer of the C. B. & Q. R. R., says:

“In general, the deterioration of coal stored in piles will be less as the distance from the surface increases. Thus the total amount of deterioration per ton of coal depends upon the width and depth of the pile. If we have a pile only five or six feet deep, as sometimes happens when coal is stored hastily without any defined system, the total amount of the deterioration per ton is going to be a great deal more than if the pile were twenty (20) feet deep, because in the smaller pile the area of exposed surface per ton is a great deal more than in the case of the larger pile.

“We stored a Wyoming bituminous coal, which was 10 per cent moisture, 16 per cent ash, 5 per cent sulphur and 11,000 B. t. u. This coal was in a pile twenty feet deep and fifteen feet broad on top. At the end of four years it was found that

* Ibid., pp. 33-34.

there had been no deterioration in this coal when a point about three feet below the surface was reached. The major portion of the deterioration was in the coal forming the flat top, which allowed the rain and snow to collect, no means being provided to shed the rain and snow."

The Consolidation Coal Company Fairmont, W. Va., reports no changes in the chemical properties of coal and less than $\frac{1}{2}$ to 1 per cent loss of calorific value after storing a 200-pound sample for a period of eighteen months.

The Westmoreland Coal Company of Irwin, Pa., says:

"This company has made some elaborate tests of the storage coal and weathering, and the results have shown that there is a very unexpectedly slight deterioration; that is to say, at least, in our coal. The coal pile oxidizes rapidly on the outside and puts on an overcoat of slack or fine coal, which seems to protect the interior of the pile and this process of greater or less oxidation and slacking goes on to a depth of, say, twelve inches or thereabouts, and underneath that we have generally found all its original value. Indeed, in some tests we have found that there has been no deterioration, even in the much more delicate tests of gassification and production of illuminating gas. We have had some coal exposed in piles, and some under cover, for some ten or fifteen years, and the general reply to your inquiry would be that there is no material depreciation."

It is difficult to differentiate between losses in storage piles due merely to natural weathering and those due to incipient or actual spontaneous combustion of the coal, also between losses in heating value and losses in coking and gas making or other properties. An effort was made to obtain information upon these points through the questionnaire, but it has not always been possible to interpret correctly the exact meaning of the answers upon these closely related subjects. The answers received to Question 13 of the Questionnaire, "Does the coal decrease in heating value as a result of storage?" were, "Yes," 21, and "No" or "Not appreciably," 20 and "Very little," 2. The percentages of depreciation given were less than 5 per cent in six cases, between 0 and 10 per cent in three, from 10 to 20 per cent in one, and from 20 to 50 per cent in one. The lower percentages probably express the same general opinion as "Very little" or "Not appreciably," and it is evident that the higher percentages mean after heating takes place.

These opinions, based mainly upon observation and experience in storing large amounts of coal under various conditions though not upon calorimetric or boiler tests, agree in general with the results of the tests of Parr, Porter, and Ovitz upon comparatively small sam-

ples or test lots, that is, that the loss in heating value due to storage alone is small and should not deter any one from storing coal through fear of any financial loss due to a decrease in heating value.

The most adverse opinion, but an interesting one, was given by A. Geschwindt, General Manager of the Rockford Electric Company, who says:

“Our experience has been that through the heating of the coal and therefore drying out, we lose considerable efficiency. If there is some method used whereby the moisture could be returned to the coal that is dried through heating, we could obtain results from this coal with less loss than we do at the present time. This is aside from that part of the coal which is actually burned while in storage pile..

“I have not been in a position to make actual tests other than laboratory tests on the value of coal that has been heated thoroughly in storage piles, but we find that in the ordinary course of burning the coal under boilers we get only half the efficiency of the boiler therefrom. While on the other hand, from testing in the laboratory we find that the coal shows not to exceed ten per cent loss.

“This is the difference between actual test of coal through the laboratory method and that of burning in the ordinary course of firing for steam.”

37. *Firing Qualities.*—There is a general opinion among firemen that stored coal is dead, and burns less freely than fresh coal. It is often condemned by them as being “no good.” Others state just as strongly that it burns better than fresh coal, but it seems to be the opinion of those who have given most careful thought to the matter that although there is no material depreciation in heating value, some coals at least, probably due to the loss of a small amount of volatile material, do not burn so freely after storage and must be fired in a slightly different manner.

Melvin Patterson, of the Brown Hoisting Machinery Company, Cleveland, Ohio, says:

“Ohio, Pennsylvania, and West Virginia bituminous coal stand the weather conditions best. The coals are piled forty and fifty feet high along the lakes. The danger due to spontaneous combustion, provided the coal is placed in the pile properly, is very slight. With the modern large grab bucket machines deterioration due to spontaneous combustion is cut to a minimum as the grab bucket can dig around the fire in less than twenty-four hours. Large operators say if they can get the coal pile off the dock in one year deterioration is negligible.”

The Fuel Station Committee of the International Railway Fuel Association concludes with regard to different coals:

“No serious consideration need be given to the question of deterioration, but each coal should be carefully studied to determine the best methods for preventing

spontaneous combustion and it is advisable to store coal from different fields in separate piles."

In connection with the six-year weathering tests* of southern and central Illinois coal, samples of nut coal from Sangamon, Vermilion, and Williamson counties and screenings from Sangamon and Williamson counties were tested under a boiler by A. P. Kratz.† He states:

"On the first test the coal banked slightly at the water-back, and the whole amount on the grate became clinkered. It immediately became evident that in order to run at all, the coal had to be kept away from the water-back. After the clinker had been removed, a fresh start was made and care was taken to keep the fuel bed from four to six inches away from the water-back. When this was done no further trouble was experienced."

The tests showed that weathered coal requires a stronger draft than fresh coal, indicating that although the weathered and fresh coals have approximately the same B. t. u. values, weathered coal is more sluggish in action.

The general summary covering the behavior of the coal in steam generation after six years of storage, according to Kratz,‡ is as follows:

"1. Burning weathered coal is largely a question of correct handling and ignition. Under these circumstances it gives as good results as fresh screenings.

"2. Weathered coal requires a little thinner fire and more draft than fresh screenings.

"3. When using weathered coal the fuel bed should not approach any nearer to the water-back than from four to six inches, otherwise trouble with clinker is experienced.

"4. Practically as high capacity was obtained with weathered coal as with other coals used, and, if anything, the fuel bed requires less attention."

These conclusions refer to burning stored coal under a stationary boiler where the draft can be much more easily regulated than in locomotive firing. If coal has become broken in storage and is burned in a locomotive, there will be an additional loss through the fine coal being carried out the stack.

Interesting information about coal exposed to the air for a long period has been furnished by John J. Davies, Commissioner of the

* Parr, Op. Cit., p. 36.

† "A Study of Boiler Losses." Univ. of Ill. Eng. Exp. Sta., Bul. 78, p. 50, 1915.

‡ Op. Cit., pp. 53-54. *Note.*—Attention is particularly called to the opinions upon this subject given in Appendix II, p. 132.

Saline County Operators Association, and A. W. Helmholtz, of the Continuous Process Coke Company of Harrisburg, Illinois. In De-Koven, Union County, Kentucky, there is a pile of approximately 30,000 tons of coal, mostly slack and supposed to have been dumped where it now lies between the hills some forty or fifty years ago. When the samples were taken, the lower part of the pile was saturated with water, but the pile had previously been subjected to weather conditions. Tests of this coal made by Helmholtz gave 9.4 pounds of water evaporated per pound of raw coal as compared with 10.3 pounds of water per pound of Saline County slack. The B. t. u. values calculated from analyses gave 11,000 as compared with about 13,500 for fresh coal presumably from the same seam and locality.

38. *Spontaneous Combustion.*—The greatest difficulty in the storage of coal is undoubtedly the tendency of many coals to fire spontaneously. As previously mentioned it is the deterioration due to this cause which is often confused with a supposed decrease of heating value as a result of storage.

The gradual heating of a coal pile is due mainly to slow oxidation of the carbon in the coal and, to a less extent, to the oxidation of the sulphur in the iron pyrites contained in the coal. If the air supply is sufficient to permit oxidation but not sufficient to carry away the heat as rapidly as it is formed, the temperature in the pile will rise gradually and finally the coal will fire. Any method of storage to be successful must be so designed that the heat generated in the pile will not exceed the heat lost by radiation. Freshly mined coal has a special tendency to oxidize and thus to heat. While this property varies with different varieties of coal, it is generally true of all coals. The greater the time elapsing between the mining and storing of any coal, the less is the liability to firing; hence, if possible, coal should be exposed to the air, that is, allowed to become seasoned before it is put in storage. This is, of course, frequently impracticable.

Oxidation of both the carbon and the sulphur takes place more rapidly as the temperature increases; hence coal stored during hot weather is more likely to heat than that stored on cool days. In spite of this fact, however, many prefer to store coal during July and August not only because of the lower price which usually prevails during these months, but because, as they say, "the coal is drier and less apt to fire."

The smaller the coal the greater is the surface area exposed to the air, the more rapid is the oxidation and the greater the tendency to heat; hence coal in lumps is not so likely to fire as fine coal, slack, or run of mine coal. If possible, the slack should be removed before storing. Great care, therefore, should be taken in handling the coal to minimize the breakage. In handling large quantities of coal this precaution cannot be given the same attention as when handling small quantities, but whenever it is impossible to screen the coal before storing and whenever sizes and kinds must be mixed, means should be provided to open the pile rapidly since heating may then be expected. Many persons believe that washed coal will not fire so readily as unwashed, because the dust has been removed.

Air currents through a pile, unless ample to carry off the heat, should be avoided since many fires seem to be due to sluggish air currents in contact with fine coal. Coal should, when possible, be piled to avoid alternate stratification of coarse and fine coal.

The opinion is wide-spread that a mixture of different varieties of coals is more liable to spontaneous combustion than a pile of a single variety, and while no explanation of this opinion has been given it is possible that the most easily combustible coal in a pile merely starts the heating and thus lowers the safety point of the less combustible coal. J. B. Porter says:

“With reference to the prevailing opinion that a pile of mixed coal is more liable to heat than one of uniform material: I can only say that my observations so far as they go bear out this opinion, but do not throw any clear light on the case. I can see no reason why a mixture of coals should be any worse than the worst coal in the lot, and I think it quite likely that this will prove to be true. There are, however, so many authenticated cases of mixed coals heating when apparently either of them would have kept safely by itself that I think we should keep on the safe side by avoiding mixtures whenever possible. I may add that the objection to mixtures is by no means confined to this continent; in fact if my memory serves me the danger of coal mixtures was first pointed out in England, and I believe in connection with East Yorkshire coals.”

A high percentage of volatile matter in coal does not of itself increase its liability to spontaneous combustion. As a result of 1200 replies received from large consumers of coal, Porter and Ovitz* concluded that there is no reason to place special confidence in smokeless coals for safety in storage. In the large stock piles at Panama, Appalachian coals, with seventeen to twenty-one per cent of volatile

* “Deterioration and Spontaneous Heating of Coal in Storage.” U. S. Bureau of Mines, Technical Paper 16, pp. 9-10, 1912.

matter, give a great deal of trouble from spontaneous fires. Several large works report, moreover, that their low-volatile coals are more troublesome with respect to spontaneous fires than their high-volatile gas coals.

The high-volatile coals of the West, are, to be sure, usually very liable to spontaneous heating, but owe this property to the chemical nature of their constituent substances rather than to the amount of volatile matter that they contain. Strange as it may seem, the oxygen content of coal appears to bear a direct relation to the avidity with which coal absorbs oxygen; high oxygen coals absorb oxygen readily, and, therefore, have a marked tendency to spontaneous combustion.

Formerly the gradual heating of the coal and its final spontaneous combustion was thought to be entirely or largely due to the presence of sulphur. The chemical studies of Parr, Ovitz, Porter, and others have shown that a coal may heat as a result of the oxidation of the carbon, even when pyritic sulphur is absent. If pyritic sulphur is present, however, oxidation of this sulphur takes place, thereby supplying a definite additional source of heat and assisting in the oxidation of the carbon. The oxidation of the sulphur also acts mechanically to break up the coal; thus by increasing the amount of small coal, the tendency to fire is increased.

Although sulphur has been shown to be only one of the factors producing heat, it is still thought by many who store coal to be the determining element in the heating of coal.

J. G. Crawford* noted piles of coal containing from four to five per cent of sulphur which had been stored on the ground from four to six years without firing.

Stansfield† says:

“Pyrites, by weathering, could hardly heat itself up to ignition point, much less the coal surrounding it; in fact, heaps of pyrite free from carbonaceous material are never known to fire spontaneously.

“In considering these arguments we must remember that there are different varieties of pyrites, that known as marcasite weathering much more rapidly than the ordinary variety. The fine flakes of pyrites, sometimes scattered throughout the coal, are probably marcasite and certainly weather faster than the larger lumps.

* Proceedings, International Railway Fuel Association, Vol. VII, p. 295, 1915.

† “Spontaneous Combustion of Coals,” An Investigation of the Coals of Canada, Vol. VI, pp. 110–111, 1912.

“A single match may ignite a pile of shavings, a single flake of marcasite might cause a warm spot that might result in a coal pile firing. This might explain the fact that the tendency for a coal pile to fire is not proportional to the percentage of sulphur or pyrites present.

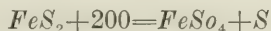
“We are not at present looking for something to heat the coal to its ignition point, but only to give it a little initial heating. If sulphur is liberated from pyrites and oxidizes (both actions being accompanied by an evolution of heat) at low temperatures, it might easily act as a starter, although the sulphur did not remain as such to lower the ignition point.

“The crucial question seems to be, does the coal or the pyrites generate heat the faster by its normal oxidation at low temperatures? The evidence seems to be strongly in favor of the answer: the coal. This would thus rule pyrites out of account as the usual causes of fires. It is, of course, always conceivable that under certain circumstances this might be reversed and the pyrites blamed; but this probably seldom or never occurs.

“On one point all parties are agreed. When flakes of pyrites weather they expand and fracture the coal, and thus expose more and fresh surfaces for oxidation and indirectly increase the danger of heating.”

Near Danville, Illinois, the Missionfield Mining Company has a plant for separating pyrite from the coal and preparing the pyrite for market. According to the superintendent of the plant, even the fine pyrite passing through a 7/16-inch screen has never fired in the bin, except when there has been found in the pile a piece of wood or other carbonaceous substance which has acted as a match to start the combustion.

In spite of the results of tests the opinion prevails very generally that a high sulphur coal is more likely to fire than one containing a small amount of pyrite, and an investigation should be undertaken to show the exact influence in storage piles of the sulphur content. It has been suggested that the pyrite may oxidize and set the sulphur free according to the reaction.



and that the free sulphur having a low ignition point may act as an igniter as it does in a match or in gunpowder. It is certainly true that on many weathered coal dumps there is a deposit of yellowish white material which very closely resembles free sulphur.

The effect of moisture upon the heating of coal is a much disputed question, although those who store coal are practically unanimous in the opinion that water stimulates spontaneous combustion. On the other hand scientific investigations seem to indicate that coal

oxidizes less when wet than when dry.* The effect of water in disintegrating coal high in sulphur is undoubted. Vivian Lewes, of England, draws a sharp distinction between wet coal and damp coal, the latter being considered dangerous. The undoubted fact that the top of a coal pile is warm after a rain is explained by the New South Wales Commission as due not to the fact that the water causes the coal to heat, but the pile being already hot inside heats the water which runs down into the pile and then returns as steam to the surface and heats it.

Stansfield† says: "It is probable that when our knowledge of the air circulation and rate of oxidation in coal piles is increased, water will be a good servant; at present it is a dangerous ally."

Coal immersed in water does not deteriorate to any extent chemically nor does it disintegrate except as a result of handling. The amount of water absorbed does not affect the burning qualities of the coal.

Instances in which water seemed to assist in stimulating spontaneous combustion are quoted in connection with reports regarding coal stored by railroads. A pile is reported to have fired under conditions in which seepage from the water tank kept part of the pile damp. Another instance occurred in a low corner of a coal pile where water collected, but this corner was shut in by a side hill which excluded the air so that it is a question which agency caused the firing, the presence of the water or an insufficient amount of air.

Most of the answers to the questionnaire agree in advising against storing on the ground on account of the presence of moisture, but an equally strong reason lies in the desirability of having a clean surface from which the coal may be taken up.

39. *Coking and Gas Making Properties.*—There are few recorded data concerning the effect of storage upon the coking properties of coal, although the replies to the questionnaire agree generally in the opinion that heating injures the coal for this purpose. H. D. Hall, Superintendent of the By-product Plant of the Inland Steel Company, says that the gas made from stored coal does not differ materially from that made from fresh coal. H. C. Porter, of the H. Koppers Company, says that the weathering of coal in the open has

* A most comprehensive discussion of this subject by Edgar Stansfield, of McGill University, will be found in *An Investigation of the Coals of Canada*, Vol. VI, pp. 95-120, 1912.

† *Ibid.*, p. 115.

a considerable effect upon the coking qualities. A. Ives, Superintendent of the American Zinc Company of Illinois, says that coal which is kept on the ground for more than thirty days deteriorates to an extent which renders it almost useless for gas making.

Tests to determine the effects of the age of coal on coking qualities, made by J. B. Porter in Canada on coals varying in age from one week to twenty-one months, showed that while in the majority of cases the difference in the coke was very slight, in some cases there was a marked deterioration of the coking quality of the stored coal.

J. B. Porter* says: "The coking quality of coal, even when stored carefully in sacks, does deteriorate somewhat with age, although not as much as is sometimes supposed, a fact which was confirmed by later tests on comparable coals. It was, however, shown that different coals varied very much in their susceptibility to aging."

"White has found," according to Porter,† "that weathering materially lowers the hydrogen-oxygen ratio, and as suitability for coking decreases rapidly as this ratio falls below fifty-nine per cent, it is easy to see that a relatively small amount of weathering may produce a profound effect on the coking qualities of a coal in which this ratio is close to this limit."

A. R. DeHoll, Superintendent of the By-product Coke Department of the Inland Steel Company, says:

"We know by experience that if the coal is heated to such an extent that smoke appears, the coke resulting from this coal is merely a conglomerate of small pieces. The coal seems to have lost its cementing qualities and at the same time the heating value of the gas will decrease from forty to fifty B. t. u. In the cases wherein we were troubled with coal thus affected I have found that the yield of ammonia was only slightly affected, but the yield of tar more so.

"In order to eliminate this trouble, I always use up the oldest coal, and when the shipping season stops at the first of December we reclaim the coal for our ovens on day turn in such a manner as to leave in our storage place room for coal taken from the opposite end of the pile. Thus by turning and airing the coal we have effectively eliminated coal fires in our operation."

Experiments made under a coöperative agreement between the U. S. Bureau of Mines‡ and the Gas Experiment Station of the University of Michigan upon West Virginia and Pennsylvania gas coals showed that coals, after being kept in storage for periods up to five

* An Investigation of the Coals of Canada, Vol. VI, p. 27, 1912.

† An Investigation of the Coals of Canada, Extra Vol., p. 172, 1915.

‡ White, A. H., and Baker, Perry, "Coals Available for the Manufacture of Illuminating Gas." U. S. Bureau of Mines, Bul. 6, 1911.

years, showed changes in their gas making properties too small to be detected by the present methods of testing and analysis. Prof. A. H. White, of the University of Michigan, says:

“The coal was piled seven to nine feet deep in bins with separate compartments so that the coal was not moved until the time came for its particular compartment to be tested. The temperature of the coal in the pile was measured during the first few months and no spontaneous heating was detected. This is important because it is known that coal which has heated is inferior as a gas coal. The coal was exposed freely to all the effects of the climate of Southern Michigan, which is rather damp and with rather severe winters.

“The main body of the coals suffered little physical change during the five years but the top six inches crumbled considerably. Chemical analyses of the coal failed to reveal any material change, even in this top six inches, after weathering five years. Neither was there any material change in the absolute weight of the coal. Samples of the coal immersed in running water showed rather more change in chemical composition than did the coals exposed to the weather.

“Gas coals of this type can be exposed to the weather in a rather severe climate for five years (provided they do not heat in storage) and at the end of the five years still be entirely satisfactory gas coals.”

There is little evidence to support the opinion that the value of middle west coals for gas making decreases as a result of storage, since these coals have not been used for gas making until recently.

40. *Degradation or Breakage.*—In connection with the storage of coal, degradation, i. e., the breakage of large lumps into smaller sizes, is the result of:

- (1) A physical change due to weathering which causes the lumps to crack and break.
- (2) Breakage due to handling.

Coals in storage alternately dry out and absorb moisture. This process tends to break up the lumps; also, flakes of pyrites oxidize and assist in the breaking up process. Coals of high moisture content in general deteriorate from breakage due to weathering.

Professor Parr* presents results with reference to the degradation of coal stored one and one-half and six years. These results are given in Table 6.

* “Effects of Storage upon the Properties of Coal.” Univ. of Ill. Eng. Exp. Sta., Bul. 97, p. 35, 1917.

TABLE 6

INCREASE IN FINE MATERIAL AFTER ONE AND ONE-HALF AND SIX YEARS OF STORAGE

(Basis of Reference, the Total Coarse Material in the Original Coal Passing Over $\frac{1}{4}$ inch Screen)

Table No.	Coal and County	How Stored	Initial Storage	After 1½ Years		After 6 Years	
			Dust Passing $\frac{1}{4}$ -inch Screen	Dust Passing $\frac{1}{4}$ -inch Screen	Increase in Per cent of Original Coal over $\frac{1}{4}$ -inch	Dust Passing $\frac{1}{4}$ -inch Screen	Increase in Per cent of Original Coal over $\frac{1}{4}$ -inch
1	Nut: Sangamon.....	Open	1.2	13.2	12.1	31.9	31.0
2	Nut: Vermilion.....	Open	13.6	24.0	12.0	35.0	24.7
3	Nut: Williamson.....	Covered	1.4	11.0	11.1	13.9	12.6
4	Screenings: Sangamon.....	Covered	26.3	38.5	16.5	45.1	25.5
5	Screenings: Vermilion.....	Open	37.7	48.4	17.1	49.6	19.1
6	Screenings: Williamson.....	Covered	38.8	45.4	10.7	50.6	19.2

Parr concludes from the results of these tests that the rate of disintegration is consistent for a given variety of coal and suggests that the oxidation of the organic material may be as largely responsible for this breaking down of the particles as the oxidation of the finely divided pyritic sulphur. The sulphur may or may not be distributed through the texture of the coal; this characteristic has not been determined for Illinois coal.

The amount of degradation depends upon the variety of coal, the method of handling, and to some extent upon the time the coal is in storage. The effect of time depends somewhat upon the size of the storage pile, since the depth to which the deterioration extends into any pile is not very great.

Breakage of coal in handling is a matter of great importance where close sizing is practiced for domestic use, not only because it increases the amount of fines and thus the liability to firing, but also because it means rescreening and additional cost. There is very little reliable information on this subject at present.

In experiments* to determine the extent of breakage of Illinois coal falling through different heights and upon different materials, such as steel, concrete, and wood, L. A. Mylius found that wetting the coal thoroughly before dropping seems to decrease breakage materially. Each coal has in itself a tendency to break which does not vary so long as the moisture content is the same. As a given coal gradually dries out its friability increases; thus a coal dried in storage with a decrease of from fifteen to eight per cent in moisture will break more readily on rehandling, owing to the change in moisture content alone. A coal which is wet before being handled seems to suffer less breakage from handling than one which has not been wet, but these statements should be more thoroughly tested before being presented as conclusive. In one of the discussions on coal storage at the International Railway Fuel Association it was stated that there was less breakage when the coal was handled wet.

The apparatus used for Mylius' tests, as shown in Fig. 56, consists of a steel framework inside of which a box is raised and lowered by means of ropes passing over pulleys at the top and attached to a small hand operated roller. The hinged bottom of the box can be dropped very quickly by means of strong springs.

Tests on the degradation of coal, made by Porter and Ovitz† are described as follows:

"Fig. 57 shows the results of some comparative breakage tests made on lump coals to bring out this point. A 50-pound sample of screened lump (over 2 inches) was dropped four times from a height of six feet and the coal then sized by screening into three portions, $\frac{1}{8}$ inch, $\frac{1}{8}$ inch— $\frac{1}{2}$ inch and $\frac{1}{2}$ inch—2 inches. The great friability of the low-volatile Appalachian coals is clearly shown and the wide variation between different coal types. It is found in practice that dust and fine coal, when mixed with some larger coal, add greatly to the danger of spontaneous heating. A single instance from commercial practice will serve to illustrate this. The Calumet and Hecla Mining Company has three large coal storage piles of 125,000 to 200,000 tons each, in which they store lump coal passed over $1\frac{3}{4}$ -inch bar screen just before placing on the piles. No spontaneous fires have occurred since they began this practice, although several fires had been experienced in the same kind of coal before that time."

The following values given by R. V. Norris‡ for anthracite coal

* These experiments have been carried on in the laboratory of the Department of Mining Engineering at the University of Illinois, but they have been interrupted by the withdrawal of Mr. Mylius to join the Canadian Army, and no conclusive results are available for publication at this time.

† "The Spontaneous Combustion of Coal." Original Communications, Eighth International Congress of Applied Chemistry, Vol. X, pp. 264-266, 1912.

‡ "The Storage of Anthracite Coal." Trans., Am. Inst. of M. E., Vol. 38, p. 314

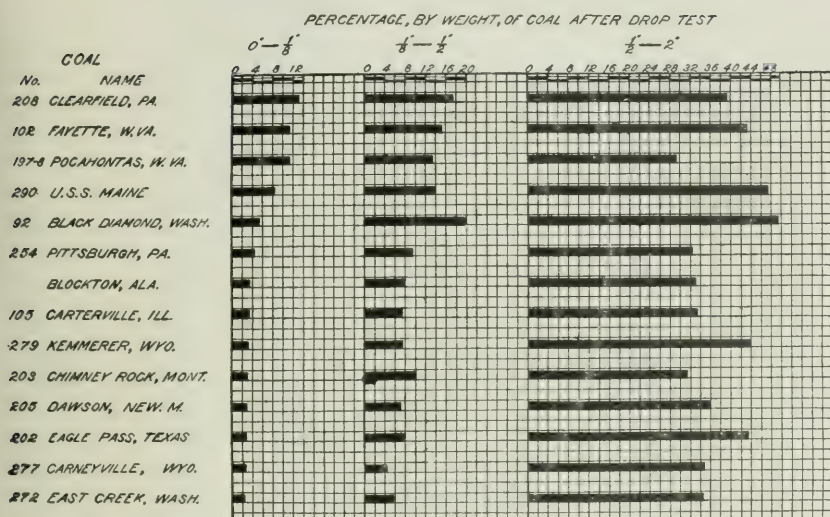


FIG. 57. CHART SHOWING EXTENT OF BREAKAGE IN A 50-POUND SAMPLE OF SCREENED LUMP COAL (OVER 2 INCHES) DROPPED FROM A HEIGHT OF SIX FEET IN PER CENT OF ORIGINAL SAMPLE

(From "The Spontaneous Combustion of Coal" by Porter and Ovitz)

show the commercial importance of degradation from handling, because with practically all bituminous coals the amount of degradation would be much greater than for anthracite although the depreciation in value for bituminous would not be so marked, except when bituminous coals are intended for domestic purposes.

"LOSS IN UNDERSIZE IN PASSING THROUGH STORAGE BINS

Size of Coal	Breakage into Smaller Prepared Sizes Per cent	Breakage into Small Sizes Per cent	Total Breakage Per cent
Broken.....	19.57	6.80	26.17
Egg.....	10.18	8.50	18.68
Stove.....	4.92	8.14	13.06
Nut.....	.....	7.65	7.65
Pea.....	.....	10.83	10.83
Buckwheat.....	.....	4.06	4.06

"Even taking half these figures, which would be most conservative, and assuming perfect rescreening, the loss at seaboard on 1,000,000 tons of prepared and pea-coal in about the usual proportions would amount to \$545,000, as shown in the following table:

Size	Original			Final		
	Quantity	Price per Ton	Total Value	Quantity	Price Per Ton	Total Value
	Tons			Tons		
Broken.....	130,000	\$4.75	\$ 617,000	96,040	\$4.75	\$ 456,190.00
Egg.....	225,000	5.00	1,125,000	191,770	5.00	958,850.00
Stove.....	195,000	5.00	975,000	192,410	5.00	962,050.00
Nut.....	200,000	5.00	1,000,000	215,040	5.00	1,075,200.00
Pea.....	250,000	3.25	812,500	248,630	3.25	808,047.50
Buckwheat.....		2.50		35,515	2.50	88,787.50
Rice }						
Barley }		1.75		20,595	1.75	36,041.25
Total.....	1,000,000	.....	\$4,529,500	1,000,000	.....	\$4,385,166.25

"The loss in breakage, from this calculation, is 54.5 cents per ton, in addition to the cost of storage.

"Many attempts have been made to reduce the breakage involved in handling through pockets, and this is often minimized by the use of shallow pockets, with resultant loss of storage; counter-chutes, spirals, and shelf-chutes in the deeper pockets, and the use of feeding-shafts, which, when properly maintained and intelligently used, keeping them full, feeding in at the top as the coal is discharged from the bottom, certainly greatly reduce the losses by dropping."

Breakage may be diminished by sliding coal along chutes or along the side of the pile rather than by dropping it. Coal moving in a large mass breaks less than single lumps. Drawing coal from the bottom of a pile under pressure results in heavy breakage. Handling prepared coal by scraping conveyors produces a breakage loss of from two to four per cent, according to the method of feeding and discharging, there being very little breakage during transit. Bucket elevators cause breakage of from two to five per cent according to the method of feeding and the discharging.

The commercial importance of the breakage problem in connection with the handling of coal is discussed very fully by Prof. E. A. Holbrook.*

* "Dry Preparation of Bituminous Coal at Illinois Mines." Univ. of Ill. Eng. Exp. Sta., Bul. 88, 1916.

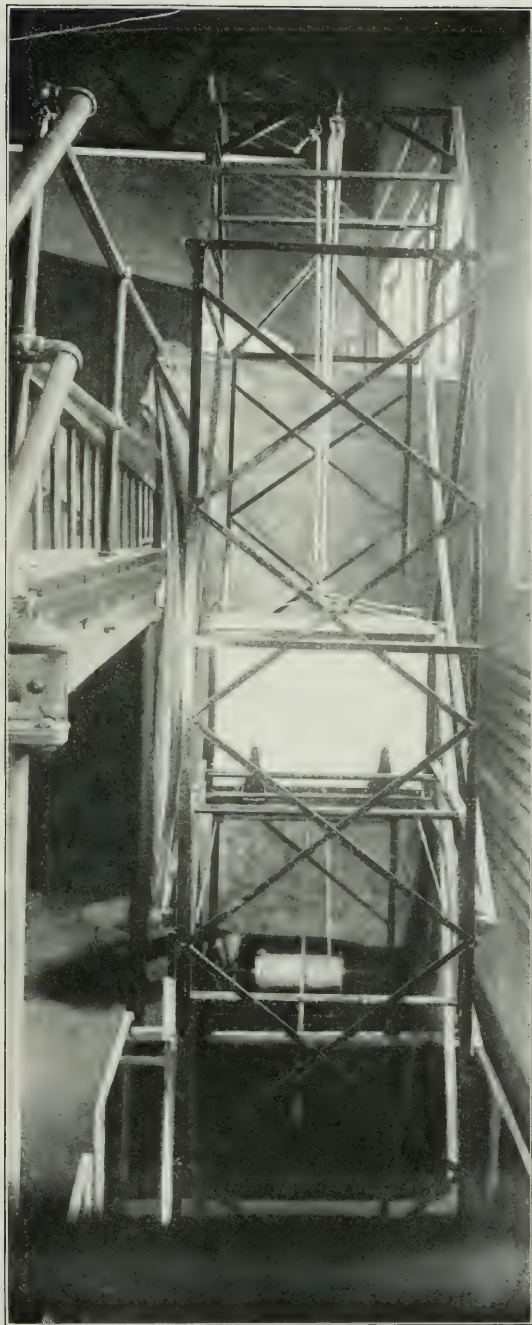


FIG. 56. APPARATUS USED TO DETERMINE THE EXTENT OF BREAKAGE IN COAL
CAUSED BY DROPPING IN TESTS AT THE UNIVERSITY OF ILLINOIS

41. *Loss in Weight.*—The loss in weight due to exposure to the air is a matter which seems to be generally misunderstood. Such loss undoubtedly occurs whenever the water evaporates from the coal. Since water, however, is not a heat producing element, but rather is a heat absorbing one, the loss in weight is an advantage, because pound for pound the coal has a higher heating value after the water has been evaporated than before. It has been shown by M. L. Nebel* that coal as it occurs in the ground is probably saturated with moisture and, although the moisture gradually dries out, it may be returned to the coal by immersing it in water. This fact of course has no practical application in the utilization of the coal, except in connection with the determination of its specific gravity.

VII. EXPENSE OF STORING COAL

Statements and estimates of the expense of storing and reclaiming coal have been submitted by many public service corporations, industries, coal dealers, and railroads. These estimates vary widely according to the conditions under which the storing is done and, for this reason, are not directly comparable. The reports were submitted in response to the questionnaire, the form of which is shown on page 130, but in only a few cases did the replies contain detailed facts such as, for instance, the expense due to depreciation, interest, rental, insurance and overhead. Many stated that it was impossible to report these items separately. The estimates are summarized in the following list in which are also given page references indicating the number of the page in this circular on which more detailed information regarding the conditions of storage may be found. A study of these conditions is essential to a correct interpretation of items of expense reported.

Other statements of the expense of storage may be found in the Proceedings of the International Railway Fuel Association.†

* "Specific Gravity Studies of Illinois Coals." Univ. of Ill. Eng. Exp. Sta., Bul. 89, p. 6, 1916.

† Vol. VI, 123, Vol. VII, 263-264, 265-266, 267-268.

EXPENSE OF STORING AND RECLAIMING COAL

<i>Firm</i>	<i>Storing</i>	<i>Reclaiming</i>	<i>Total</i>
<i>Hand Storage</i>			
<i>Bohmer Coal Company, St. Louis, stored on ground and reclaimed by hand shoveling</i>			\$.15-.30
<i>St. Bernard Mining Company, Nashville, Tenn., dumped from wagons, reclaimed directly into wagons, p. 163</i>	\$.22		
<i>Polar Wave Ice and Fuel Company, St. Louis, hand labor, p. 161</i>	.48	\$.16	.64
<i>Crystal Ice and Fuel Company, Danville, Ill., stored in bins by dumping, reclaimed by shoveling, p. 159</i>			.17
<i>Ebner Ice and Cold Storage Company, Vincennes, Ind., by hand labor and conveyors, p. 161, for depreciation and interest, .154 cents, also under water .214 cents</i>			.368
<i>Rock Island Fuel Company, Rock Island, Ill., labor only, p. 159</i>	.08	.10	.18
<i>University of Illinois Storage with motor truck and by hand, reclaimed by wagon loader, p. 42 and 47</i>	.21-.34	.20	.41-.54
<i>Side Hill Storage, estimated in 1907, p. 56</i>			.19
<i>Locomotive Crane Storage</i>			
For cost of locomotive cranes, see page 60.			
Estimated expense of operating locomotive crane, \$1.50 per hour, or 3 cents per ton.			
<i>A large wholesale and retail coal company</i>	.015	.02	.095*
<i>Commonwealth Edison Company, Chicago, labor and materials only, p. 61</i>	.05	.05	.10
<i>Clinchfield Fuel Company, Dante, Va., Crane and trestle, p. 64 and 67</i>	.0671	.0655	.1326
<i>A large wholesale and retail company</i>			.04-.20
<i>Pittsburgh Plate Glass Company, Crystal City, Mo., p. 165</i>	.25	.25	.50
<i>Rockford Electric Company, Rockford, Ill., p. 165</i>	.10	.10	.20
<i>American Zinc Company, E. St. Louis, Ill., p. 171</i>	.20	.15	.35
<i>Crerar-Clinch and Company, Chicago, hand and locomotive crane, p. 161</i>			.25

*This total includes \$0.04 for interest and \$0.02 for depreciation.

<i>Firm</i>	<i>Storing</i>	<i>Reclaiming</i>	<i>Total</i>
<i>Locomotive Crane Storage—Cont'd</i>			
<i>Mineral Point Zinc Company, Depue, Ill.,</i> p. 171	\$.05-.06	\$.05-.06	\$.10-.12
Estimate by C. G. Hall			.2628
<i>Missouri, Kansas and Texas Ry., including cost</i> <i>of track, p. 183</i>	.035	.035	.07
<i>Chicago, Lake Shore and South Bend Ry., p. 181</i>			.12
<i>Grand Trunk Pacific Ry., p. 184</i>	.08	.062	.142
<i>Atlantic Coast Line, p. 183</i>			.04-.05
<i>Central of Georgia Railroad, p. 180</i>	.0258	.0209	.0467
<i>Steam Shovel Storage</i>			
<i>Union Light and Power Company of St. Louis,</i> <i>dumped by hand, reloaded by steam</i> <i>shovel, p. 167</i>	.10	.10	.20
<i>Bridge Storage</i>			
<i>Wisconsin Gas and Electric Company, Racine,</i> <i>Wis., p. 166</i>	.08	.22	.30
<i>Berwind Fuel Company, Duluth, Minn., p. 82.</i>			.60
<i>Link-Belt Company, estimate for bridge stor-</i> <i>age, p. 82</i>	.056	.0515	.1075
<i>Calumet and Hecla Mining Company, Calumet,</i> <i>Mich., Hunt system, steam shovel, p. 174</i>			
Summer	.15	.07½	.22½
Winter	.15	.11¼	.26¼
Large swivel bridge, p. 82		.06	
<i>Under-water Storage</i>			
<i>New Kentucky Coal Company, Kankakee, Ill.,</i> <i>Storage of 250,000 tons, \$20,000-\$30,000,</i> <i>pp. 100 and 101</i>			
<i>Metropolitan Water District, Omaha, Nebr.,</i> p. 102	.063	.063	.126
Estimate by C. G. Hall, p. 106			.1823
<i>Peabody Coal Company, Lemont, Ill., pp. 104</i> <i>and 105</i>			
Estimated expense of operation			.162
Estimated cost of equipment, \$13,830			
<i>Illinois Traction System, see pp. 88 and 89, for</i> <i>cost of plant</i>			
<i>Western Electric Company, Chicago, p. 88</i>	.05	.04	.09
<i>National Zinc Company, Springfield, p. 90 1913</i>			.225
" " " " 1917	.10	.10	.20

APPENDIX I

QUESTIONNAIRE ON COAL SHORTAGE DATA

1. Kind of Coal Stored	State and District Where Coal was Mined	Sizes Stored	Amount Kept in Storage
.....			
Semibituminous			
(Pocahontas, Central Pa., W. Md.)			
Bituminous			
Note: Please give definitely the district in each state from which the coal comes.			
2. How long is coal kept in storage?			
3. Are sizes kept separate in storage?			
4. Is slack removed before storage?			
5. How long time elapses between the mining and storing?			
6. What do you consider the best months to store?			
7. Why do you consider this the best time to store?			
8. Why do you store coal?			
9. What do you consider the financial advantages of storing?			
.....			
10. For what purpose is the stored coal to be used?			
11. Is there any difference in the selling price of fresh and stored coal?			
.....			
12. Does the coal decrease in heating value as a result of storage?			
..... If so, to what extent?			
13. What loss is there through breakage as a result of storing and reclaiming the coal?			
14. Does the coal heat up after being stored?			
If so, how soon?			
15. What measures are taken to prevent heating?			
16. In case of heating, how is coal handled?			
17. To what extent is coal injured by such heating?			

- | | | | |
|-----|---|---------|------------|
| 18. | What method of storing is used? | ..... | ..... |
| 19. | What method is used for reclaiming the stored coal? | ..... | ..... |
| 20. | Is coal stored on the ground? | ..... | ..... |
| 21. | If not on what is the pile built up? | ..... | ..... |
| 22. | Is pile continuous or divided by partition wall? | ..... | ..... |
| 23. | Is storage under cover? | ..... | ..... |
| 24. | What is the shape of the storage piles? | ..... | ..... |
| 25. | What is the height of the storage piles? | ..... | ..... |
| 26. | What machines are used for storing? | ..... | ..... |
| 27. | What machines are used for reclaiming? | ..... | ..... |
| 28. | Are these machines satisfactory? | ..... | ..... |
| 29. | If stored under water what percentage of water is retained by coal when taken from storage? | ..... | ..... |
| 30. | In storing are lumps allowed to roll down and accumulate at bottom of pile? | ..... | ..... |
| 31. | What percentage of fines below $\frac{3}{4}$ inches are present when stocked? | ..... | ..... |
| 32. | Cost of | Storing | Reclaiming |
| | Overhead | ..... | ..... |
| | Labor | ..... | ..... |
| | Supplies | ..... | ..... |
| | Depreciation on mechanical equipment | ..... | ..... |
| | Interest on investment | ..... | ..... |
| | Rental on land on which coal is stored | ..... | ..... |
| | Insurance on equipment | ..... | ..... |
| | Insurance on coal | ..... | ..... |
| | Totals— | ..... | ..... |

Note: If itemized costs are not available please give totals and state what totals include.

33. Please give reference to any articles which have appeared descriptive of your storage.
34. Information furnished by
- Official position
- Company

APPENDIX II

SUMMARY OF CONCLUSIONS AND SUGGESTIONS

REGARDING COAL STORAGE

THE questionnaire, presented on page 130, was sent out to a large number of firms and individuals and on the basis of replies a summary of conclusions and suggestions was prepared. This summary included as nearly as possible all the suggestions regarding coal storage contained in the replies. It was then sent to those who had replied to the questionnaire for an expression of opinion and the request was made that reasons for disagreement be given. The responses were most gratifying, not only because there was a general agreement with the conclusions, but because so much care was evidently taken in studying the summary. In many cases no answers were given to certain questions, possibly because the persons replying had had no experience with the particular phase of the subject in question and did not, therefore, wish to express an opinion. Certain answers of "NO" also do not indicate disagreement from the conclusions, but merely that the conclusion outlined does not represent the practice of the person answering the question or that the person has had no experience with that phase of the question.

The answers have been tabulated under three heads: YES, NO, and DOUBTFUL (?). The question mark does not necessarily imply that the conclusion is questioned, but may mean merely that the person replying had no data upon which to base an opinion. The tabulation of replies is presented, in the form in which the summary was submitted to firms and individuals, as follows:

CONCLUSIONS AND SUGGESTIONS REGARDING COAL STORAGE

(Submitted to 175 corporations or individuals storing coal)

It is impossible to give definite rules and regulations regarding the storage of coal which will be universal in their application and each storage problem must be solved in accordance with such local conditions as the kind of coal to be stored, the space and appliances available, the capital obtainable, etc. The following are some suggestions which seem fairly to represent the results of present storage practice and of certain theoretical considerations based upon experimentation.

Coal is stored:	Yes	No	?
1. To assure a regular supply when the mines are shut down or when coal is not delivered regularly by transportation companies	84		
2. To take advantage of low water freight rates	78	6	
3. Because the price is often less at certain seasons of the year, generally in the summer	87	6	
4. To equalize the prices on the different sizes of coal	65	11	5
5. To avoid the maintenance by the railroads of equipment which is used for only a part of the year	74	2	1
6. Coal storage should not be considered only as a war expedient but as an essential part of all large coal using operations	81	1	
7. Coal should be stored as near as possible at a point where it is to be used so as to avoid rehandling and to equalize transportation facilities	79	2	
8. There is a considerable difference in the ease with which different coals oxidize and this must be considered in storing coal	78		
9. Coal exposed to the air seems to lose some of the volatile ingredients which assist in producing spontaneous combustion; hence the greater the time elapsing between the mining and storing of the coal, the less is the liability to spontaneous combustion	64	4	5
10. The opinion formerly held that the chief source of spontaneous combustion is the pyrites (sulphur) in the coal has not been substantiated by experiments. There is, however, a wide-spread opinion that coals high in sulphur are much more liable to spontaneous combustion than those low in sulphur and an effort is made by many in choosing a coal for storage to get one low in sulphur	65	3	5
11. Although the oxidation of the sulphur is not the principal heat producing element, it tends to break up the lumps and thus increases the fine coal which fires easily	71		7
12. Some coals and particularly those high in sulphur heat more readily if damp, and alternate wetting and drying is undoubtedly harmful.	76		2

	Yes	No	?
13. All varieties of bituminous coal may be stored if of a proper size, if the fine coal and dust have been removed, and the coal is so handled that dust and small coal are not produced in the storing in excessive amounts . . .	76	4	2
14. Most varieties of bituminous coal are liable to spontaneous combustion if the fine coal is not removed before storage	79	1	3
15. In storing coal handle it so as to produce a minimum of dust and fine coal	78	1	
16. Owing to the cost of screening, to the difficulty of arranging for it in large storage piles and to the difficulty of disposing of the screenings, it is often not practicable to store lump or screened coal	74	5	1
17. Unless lump and screened coal are piled carefully and in low piles, crushing is likely to take place and produce dust near the bottom of the pile and thus to start spontaneous combustion	69	6	3
18. Pile as uniformly as possible and avoid stratification of large and small lumps	75	4	
19. As liability to spontaneous combustion increases with the temperature, the cooler the coal is when stored, the less is the liability to spontaneous combustion . . .	72	5	2
20. Coal stored in cold weather is less likely to give trouble than that stored in summer and where summer storage is necessary the liability to heating is much less if the storage is carried on on cloudy or cool days . . .	70	7	3
21. Coal of different varieties should not be mixed in storage if this can be helped, since such mixture seems to increase the liability to spontaneous combustion . . .	72	6	4
22. All storage appliances and arrangements should be so designed as to make it possible to load out the coal quickly	83		
23. Coal should not be stored in large piles unless provision is made for loading it out quickly in case of spontaneous combustion	72	3	
24. Since moisture from below assists spontaneous combustion the storage pile should rest on a dry base . . .	74	2	1

	Yes	No	?
25. Since a small amount of water seems to aid spontaneous combustion, the drier the coal is when stored and during storage, the less is the liability to spontaneous combustion	72	1	5
26. Do not allow pieces of wood, greasy waste or other easily combustible material to be mixed with the coal during storage since they may form a starting point for a fire	78	2	
27. Avoid contact between the coal and all such external sources of heat as steam pipes	82		
28. Pile coal as uniformly as possible and do not allow the lumps to roll to the bottom or to one side of the pile and thus form a flue for the entrance of air to the interior of the pile	72	2	2
29. Avoid air channels in a coal pile such as occur about imbedded pipes, the bents of trestles, cracks through bulkheads, etc., since fires frequently originate near such air channels	67	3	2
30. Unless coal can be piled so that air can thoroughly circulate through the pile and thus carry off the heat as rapidly as it is generated (this is very difficult to accomplish), the more closely fine coal is piled to exclude air the better	65	3	3
31. Ventilation of coal piles by means of pipes running through the pile has usually not been successful in preventing spontaneous combustion, because the air does not circulate freely throughout the pile and in some cases the air currents through these pipes seem to be starting points for fires	63	2	3
32. The great objection to ventilating systems is that they interfere with the handling of the coal	75	1	
33. There is great difference of opinion in regard to the height of piles in which coal may be stored safely. Coal seems to fire almost as quickly in low piles as in high and as often near the top or outside of a high pile as near the bottom. The principal disadvantage of high piles is that coal in them cannot be so readily removed as from a low pile	65	5	
34. Water is not generally successfully applied in extinguishing fire in a coal pile, because it is impossible thoroughly to saturate the pile. A small amount seems to aid spontaneous combustion	73	2	

	No	Yes	?
35. The deterioration in coal stored under water is negligible. Such coal absorbs little extra moisture	74	1	
36. With under-water storage if the entire coal pile is not covered, the part of the pile above the water line is liable to spontaneous combustion	64		3
37. The white coating on the outside of some coal piles is very thin and does not affect the value of the stored coal	66	5	2
38. The best method of handling coal in danger of firing is to load it out and scatter it so that it will be thoroughly cooled off	75		1
39. Coal which has a tendency to spontaneous combustion should be turned over frequently to keep down the temperature, although this causes an increase in breakage	71	3	3
40. If possible, stored coal should not be moved until it is to be used, unless it is heating, since piles which have apparently been safe have taken fire when opened to the air and the coal moved elsewhere; probably because of the opening up of new faces for oxidation	75	1	1
41. Coal which has once heated and cooled is not subject to the same oxidizing processes as fresh coal	64	3	2
42. Coal which has been in storage is considered by many to burn less freely when fired in a furnace, but this is largely prejudice and certainly can be overcome by keeping a thinner bed on the grate than with fresh coal and by regulating the draft	60	8	2
43. The decrease in heating value as a result of storing coal is small unless the coal has heated up sufficiently to decompose the coal or to drive off the volatile ingredients and the loss of moisture from the coal may increase the heating power per pound of coal	70	1	1
44. The coking properties of eastern bituminous coals are not materially affected by storing unless the coal heats, but the coking properties of Illinois and other Middle West coals are seriously affected or destroyed by storage	53	1	4
45. The best preventive of loss in coal storage is the constant inspection and watching of the coal for incipient heating and immediate removal of coal from the spot affected	73		
46. Other suggestions			

The following is a digest of the answers given to the summary of conclusions, listed on pages 133-136, which could not be included under the headings listed as "Yes," "No," and "?". These opinions show that the experiences of those storing coal are by no means the same and that local conditions evidently have a great deal to do with the opinions expressed.

Reasons for Storing Coal

1. To assure a regular supply when the mines are shut down or when coal is not delivered regularly by transportation companies.
2. To take advantage of low water freight rates.
3. Because the price is often less at certain seasons of the year, generally in the summer or spring.
4. To equalize the prices on the different sizes of coal.
5. To avoid the maintenance by the railroads of equipment that is used for only a part of the year.

Comments:

"To have a supply on hand for special seasons, such as during the grain rush."

"To reduce cost of production at the mine by giving more uniform running time and thus utilizing labor and equipment to best advantage."

"To provide against labor unrest at the mines."

"To equalize distribution of coal."

"Make 3 to read, because the producers will often make price concessions on sized coal at certain seasons of the year (generally in the summer) which will offset the storage expense incurred by the consumer."

"Amend 4 to read: From the standpoint of the producer it is advantageous to store some sizes at the mines or at distributing centers to equalize more nearly the prices on different sizes of coal."

"Most of the large dock companies contract their tonnage at a fixed price for the season."

"Screenings may be higher in summer than in spring and fall on account of decreased operations of mines and lack of demand for screened sizes."

Advisability of Storage

6. Coal storage should not be considered only as a war expedient but as an essential part of all large coal using operations.

Comments:

"May be true at some industrial plants, never true on a railroad. The storage of coal on a railroad is done only to meet a possible shortage of coal due to mine strikes or other causes. It is always more expensive for a railroad to store coal than it is to rely upon a current supply the year around Seasonable use of equipment, or traffic conditions, would not in-

fluence the storage of coal on a railroad as the expense of handling and storing is great enough to overcome any or all these conditions.”

“Should be more zealously practiced in peace times than during war. Should be strictly limited in war times.”

Place of Storing

7. Coal should be stored as near as possible to a point where it is to be used so as to avoid rehandling and to equalize transportation facilities.

Comments:

“Rehandling is a preventive against fires and is an advantage where coal is to be used for coke and is pulverized anyhow.”

“Should be stored at point of use and at mines.”

“Preferably so, but in order to avoid transportation difficulties, rather than for the reasons given. Coal can be unloaded into storage at some intermediate point and later loaded up and forwarded to its destination on the original freight rate.”

“All modern mines should have storage at the mines as well as at point of consumption.”

“Railroads should store heavily in spring months, February 1 to May 1, so that they can serve the public and keep their locomotives and cars busy in the dull season.”

Liability to Spontaneous Combustion

8. There is a considerable difference in the ease with which different coals oxidize and this must be considered in storing coal.

Comments:

“Broadly eastern and western coal should never be stored together.”

“Not of great practical importance among the high grade Appalachian coals; applies to essentially different types of coal.”

“You can store western coals without loss and danger from heating and it becomes a question of going as close as you can to the danger line to get the storage.”

9. Coal exposed to the air seems to lose some of the volatile ingredients which assist in producing spontaneous combustion; hence the greater the time elapsing between the mining and storing of the coal, the less is the liability to spontaneous combustion.

Comments:

“The general opinion is that it is not the loss of volatile ingredients which lessens the liability to spontaneous combustion of coal which has been exposed to air for a period of time before storing, but rather it is believed that during this preliminary period of exposure to air, the surfaces of the coal have become somewhat satisfied in their capacity for absorbing oxygen and the rate of absorption becomes less. Since the oxygen combines chem-

ically with generation of heat, the faster the rate of absorption, the greater will be the tendency to spontaneous combustion."

"Think that this is due to completed oxidation and degradation of all sulphur compounds. I have never heard that the extension of time between mining and storage minimized chances of combustion. It is very interesting."

"Seems reasonable, but as car or boat must be unloaded on receipt, do not see much value in the suggestion."

"Coal which has passed through the heating process successfully, that is, without ignition may lay for years without further heating."

"Depends on whether the decreased liability of fire is more essential than the decreased coking qualities of the coal."

"Our experience has been that coal obtained from western Kentucky coal fields is much more likely to fire in storage than coal from eastern Kentucky coal fields."

"Cannot confirm conclusion, as coal that had been in storage for years took fire after it had been moved and restored."

"Do not notice any difference between storage at mines and distant points."

"Probably but not confirmed by our practice."

"The loss of volatile matter, if any, is irrelevant and immaterial; it has nothing to do with the liability to spontaneous heating which is caused rather by surface oxidation."

"I doubt this difference being enough to give it commercial consideration."

"The reason for this is probably that moisture is less."

"Is there not some ambiguity possible in this paragraph? Evidently refers to storage of coal in room at mines, not storage of coal in large quantities by mining companies at surface. Public might interpret this to mean feasibility of operators storing large quantities of coal at surface during periods of slack demand."

"Since coal has a limited absorbing power for oxygen, after the surfaces are exposed to the air for some time there is less liability to spontaneous combustion."

Effect of Sulphur on Spontaneous Combustion

10. The opinion formerly held that the chief source of spontaneous combustion is the pyrites (sulphur) in the coal has not been substantiated by experiments. There is, however, a wide-spread opinion that coals high in sulphur are much more liable to spontaneous combustion than those low in sulphur and an effort is made by many in choosing a coal for storage to get one low in sulphur.

Comments:

"There seems to be a rather general impression that sulphur is the determining factor of spontaneous combustion. In some analyses of samples which I took, the coal analyzed anywhere from four to five per cent sulphur, and this pile has been on the ground for over four years and another pile of

the same coal for a period of six years without firing. This seems to be conclusive evidence that sulphur is not the determining factor."

"Pocahontas, New River and other high grade smokeless coals, which are low in sulphur, are extremely liable to fire, undoubtedly caused by oxidation, as we have frequently found small fires within two feet of the top of a forty-foot pile and again at the floor in the very center."

"I have wondered whether pyrite and iron nail and water might not start a fire. See Watt's Dictionary of Chemistry on the Result of mixing pyrite and wet nails under a clay pot. An explosion takes place the steam blowing off the clay cap."

"We have never had trouble in storing West Virginia coal which is low in sulphur. All the coal which we stored this year and which caught on fire was high in sulphur."

"Pocahontas with lower sulphur gives more trouble than Pittsburgh with higher sulphur."

"All cases of spontaneous combustion observed have been high or moderately high sulphur coals."

"The sulphur is generally associated with elements that promote spontaneous combustion."

"This is the general practice and opinion. I cannot vouch for its correctness."

"This belief is losing strength."

"The fact that coal is low in sulphur is, in my opinion, no evidence that it is a suitable coal for storage. The coal on the Milwaukee and Western Fuel Company docks at Milwaukee have been on fire for a number of years. The coal is unloaded in the summer, immediately begins to heat and they never succeed in extinguishing the fire until the next cargo comes in the following year. This coal is $\frac{3}{4}$ -inch Youghiogheny slack containing not to exceed .75 sulphur. On the other hand I have personally stored in Louisville, Kentucky, a large tonnage of a straight creek coal containing about the same amount of sulphur and have had no trouble whatever with the same heating although the coal was piled twenty feet high and remained in storage two years."

11. Although the oxidation of the sulphur is not the principal heat producing element, it tends to break up the lumps and thus increases the fine coal which fires easily.

Comments:

"Therefore the presence of the sulphur facilitates."

"Do not concur in the conclusion, as in warm weather the heating takes place before there is time for such disintegration."

"I have stored considerable lump coal which was high in sulphur and have taken the same out of storage four or five months later and have not found that the high sulphur coal caused any more degradation than any other class of coal. I have stored the majestic lump coal from the mine in Prairie County, which is extremely low in sulphur, and have found that it breaks up fully as much as high sulphured coal."

Effect of Moisture on Spontaneous Combustion

12. Some coals and particularly those high in sulphur heat more readily if damp, and alternate wetting and drying is undoubtedly harmful.

Comments:

"Make to read most instead of some coals."

"Moisture is a cause of spontaneous combustion."

"Not true of the hard bituminous coal, like McAlester, Oklahoma, Colorado and Pennsylvania bituminous."

"All the coal that I have ever stored has been stored in the open so that same has been exposed to the weather and the alternate wetting and drying but have never noticed that this had anything to do with the coal firing, although some of the coal stored was high in sulphur and did not fire."

Relation of Size of Coal to Spontaneous Combustion

13. All varieties of bituminous coal may be stored if of a proper size, if the fine coal and dust have been removed, and the coal is so handled that dust and small coal are not produced in the storing in excessive amounts.

Comments:

"Do not think many coals can be handled in this way successfully."

"Yes, but impracticable."

"All is a sweeping word. Should prefer nearly all or probably all."

"We have never had any trouble with lump coal, but have had trouble with mine run."

"And the pile is not too high."

"Excepting unwashed screenings."

"Impracticable and almost impossible."

"Desirable; not always practicable."

"Cleaned coal undoubtedly has less liability to fire than coal with slack."

"Fine coal should be removed thoroughly or else run of mine stored. Partial ventilation worse than none."

"Some bituminous coal will slack and then is no longer sized and is likely to burn."

"Hard to do and expensive."

"Simply a matter of ventilation."

"So far I have had no experience in storing coal with the fine dust removed. In ordinary commercial undertakings where large volumes of coal are to be stored, it seldom happens that the fine dust is removed. I, therefore, do not know what effect it would have if such could be accomplished."

"All kinds may be kept if stored properly. We store dust and slack under water."

"Not practicable for railroads."

"Can store low sulphur mine run coal with slack in it if properly handled."

"I believe that the character of coal has a great deal to do with spontaneous combustion, in that a soft, porous coal which fires much more quickly than a more solid one, possibly due to additional breakage and water, and moisture absorption by the porous coal."

"As a result of our experience this year we have decided to store only lump coal in the future, getting coal that is as free from sulphur as possible. We will store it in a number of small piles of not over 1500 to 2000 tons each separating the piles by a distance sufficient to prevent the spread of fire."

"Heating in storage coal is proportional to the amount of coal surface (not pile surface) in contact with air. If the sizes of the lumps are large, the amount of surface exposed is relatively small, and so too is the amount of heat evolved. If, however, the pieces of coal are small, including a considerable amount of coal dust, the amount of contact surface is enormously increased, the amount of heat evolved is also increased, and the danger of the temperature of the coal rising to a point where active combustion will take place is much greater."

"This would indicate two principal ways of storing coal so that it will not take fire:

(1) Store large lumps only, thus reducing the amount of surface exposed to the air.

(2) Store fine coal only, packed so tightly that there will be no voids through which air can circulate."

"The friability or ease of breakage of coal is a very important factor affecting spontaneous combustion and is the cause of the prevalence of this trouble with semibituminous coals."

"Use screened coal for storage. Size of piles, kind of weather conditions, conditions of storage and sulphur content are then of minor importance."

"We cover our coal pile with fine raw dust when we discover the top or outside of the pile burning, thus preventing the air having access to coal and increasing the fire. We are able to successfully check a fire in this manner for a few weeks until we are ready to move the pile."

14. Most varieties of bituminous coal are liable to spontaneous combustion if the fine coal is not removed before storage.

Comments:

"Not high grade hard bituminous."

"It is best to store mine run coal in small piles to lessen danger of spontaneous combustion."

"To a certain extent."

"More liable."

"We have never been successful in storing either screenings or mine run coal in large piles above ground. In our storage operations at the present time we are confining ourselves to selected mine run. In making this selection we choose coal having a very small percentage of screenings in it. We find that even this selected coal when piled in large piles will start heating and eventually fire."

"Choose the right coal to store. Store screened coal if in doubt."

"I think that the quality and structure of the coal placed in storage is of more importance than the manner in which the lump or screening coal is piled. If the coal is soft, it will undoubtedly break up and in these days when labor is so scarce, it is necessary to handle more of the coal with some mechanical device, particularly by a clam-shell. This manner of handling is very rough but we have a number of piles fourteen to sixteen feet high of lump, egg and nut which have been handled in this manner and we have had no trouble with spontaneous combustion."

15. In storing coal handle it so as to produce a minimum of dust and fine coal.

Comments:

"Not practicable for railroads."

"Yes, where possible; depends on machinery, quantity, quality of coal and ground area."

16. Owing to the cost of screening, to the difficulty of arranging for it in large storage piles and to the difficulty of disposing of the screenings, it is often not practicable to store lump or screened coal.

Comments:

"Lump coal that is practically free from fines or dust is to a large extent self ventilating and therefore safe for a reasonable time if other conditions are favorable. On the other hand, fine coal entirely free from lumps which would form air pockets and chimneys may be stocked almost as safely as the lump. A combination of the two, such as run of mine, is dangerous."

"We store as much crushed coal as possible."

"There is no difficulty in disposing of the screenings. When we buy coal for storage we have it screened at the mine, and the screenings are used for our daily service."

"It is perfectly practicable to store lump or screened coal but such coal costs more per ton."

"This was true until the last few years. During 1916-17 there was a very large demand for screenings."

"Storage of screenings is dangerous under any conditions."

"Depends upon intended use of coal."

"Depends on coal."

"Coal should be screened at the mine and only the sizes not readily marketable should be stored. This probably would mean in normal times that there is a supply of lump and egg coal in the summer which would be the grade that the ordinary householder should store. At the present time it is clearly developed that the distribution of domestic coal burdens the railroads to a greater extent for the amount of tonnage involved than any other class of coal business. The movement, switching and placing in single cars results in greater delay to equipment, greater loss of efficiency from

motive power and engine crews and in every way increases the operating difficulties."

"I would say sometimes instead of often. It is generally practicable and the expense of it is generally a reasonable insurance."

Height of Pile

17. Unless lump and screened coal are piled carefully and in low piles, crushing is likely to take place and produce dust near the bottom of the pile and thus to start spontaneous combustion.

Comments:

"We have piled lump coal in piles thirty feet high and have never had trouble with spontaneous combustion."

"Crushing has not been noticed in piles twenty-five feet high. Fires start at a depth between four and eight feet."

"We do not find it so. Pile as high as sixty feet with little crushing."

"Don't store in piles over eight feet high."

"Depends on the character of the coal."

"Where coal is placed in storage, it should not be scattered over a considerable area in thin layers, but should be piled in one mass as much as possible."

"Weight is a big factor; so restrict open air storage to piles eight feet high. Under-water storage is the best."

Uniform Piling

18. Pile as uniformly as possible and avoid stratification of large and small lumps.

Comments:

"I have replied 'no' as we store in the neighborhood of 1,000,000 tons coals per year and it is absolutely impossible to avoid stratification of the large and small lumps."

"Impracticable unless the coal is put into a pit or a bin. When piled in a pyramidal pile, fine coal will stay on the ridge and the larger sizes roll to the bottom and edge."

"Impracticable to follow out this suggestion."

"Not practicable for railroads."

"True for some coals, not for others."

"It is further important that the tops of all piles be finished off as nearly level as possible, avoiding to as large an extent as possible peaks and valleys over the surface. In the unloading of coal from buckets into storage the larger lumps tend to roll to the bottom of the pile along the surface of the coal already in storage, so that unless care is taken in the dumping a coal pile will consist of fine coal in the center with a fringe of large and intermediate lumps along its edges. Fires very frequently start along these edges, for obvious reasons, and if the coal is to be kept in storage any great length of time the lumps should be either removed or the whole covered with

fine coal so as to remove from contact with the air the mixture of lumps and fines."

"Very important."

Temperature at Time of Storage

19. As liability to spontaneous combustion increases with the temperature, the cooler the coal is when stored, the less is the liability to spontaneous combustion.

Comments:

"We commence storing coal at the head of Lake Superior at the opening of navigation, but have never had fires during the summer time. They usually make their first appearance during the month of September and we have the situation well in hand prior to December 1."

"The variation in the temperature of mined coal is so slight that I question whether this would have any bearing."

"Theoretically but would not make much difference in practice."

"Believe this will effect but short delay."

"Do not believe this applies to large and deep storage. Outside temperature of no account in such cases."

"Yes, for the time being, but the pile will not be permanently safe until it has gone through a summer."

"Doubt if there is anything in this suggestion, as the majority of our fires occur after the coal has been stored for some time and bear no relation to the temperature of the coal at the time it was placed in storage, as all our coal is stored in the open."

"Possibly slight effect."

"Yes; but negligible compared with item of fine, fresh coal dust."

"In cold countries storage in the open is less liable to spontaneous combustion than storage under cover."

20. Coal stored in cold weather is less likely to give trouble than that stored in summer and where summer storage is necessary the liability to heating is much less if the storage is carried on on cloudy or cool days.

Comments:

"Difference in temperature of the coal at the time of storing may have some influence, but under ordinary conditions where large quantities of coal are stored, there is very little choice as to the time the coal can be put down."

"Naturally, we have to store our coal regardless of weather conditions."

"Perhaps at the time but doubt importance."

"Not important."

"Believe this is of little benefit."

"Do not find any difference in summer and winter storage."

"Rather a fine distinction."

"Would omit this. Impracticable."

"Yes, but how can such days be chosen?"

"Yes; but negligible compared with item of fine, fresh coal dust."

Effect of Mixing Coals in Storage

21. Coal of different varieties should not be mixed in storage if this can be helped, since such mixture seems to increase the liability to spontaneous combustion.

Comments:

"Extremely important. We have experienced no trouble with the heating of stored coal, and the only time we have ever had a fire on our dock was when we bought a number of different kinds of coal. We have our coal dock situated close to the brewery and we generally purchase our coal before the opening of navigation, and have such a capacity that the coal can come in almost as fast as the companies desire to send it to us, all, of course, coming in during the season of navigation. Our usual method is to purchase our entire season's supply from one company and secure all the coal from one mine. Mixed coals are not only objectionable on account of the danger of spontaneous combustion, but different coals require different methods of firing."

"If coal that is known to give trouble from spontaneous combustion is mixed with coal that does not, it will undoubtedly increase the liability for the spontaneous combustion of that given pile. However, if two coals are mixed together in which there is very little difficulty of spontaneous combustion, I doubt if it makes very much difference if they are mixed or not."

"Believe this effect is more a result of stratification than of difference of quality."

"Probably true and vital to docks storing large quantities of coal."

"We mix our coals."

"Not borne out by our experience."

"We have not found this to be true."

"Should never be mixed in pile."

"Highly important."

"Do not believe this."

"Coal stored from different mines together if not submerged appears inadvisable."

"Depends on meaning of varieties; in general, yes."

"Know case where two coals, which in themselves will not fire, yet fired when stored together, but a few tons of coal which fires readily will set a pile on fire. May be likened to a hot cigar ash or match thrown into a waste basket."

"Have not heard of any evidence of this; do not see any reason to believe it."

Precautions Which Prevent Fires

22. All storage appliances and arrangements should be so designed as to make it possible to load out the coal quickly.
23. Coal should not be stored in large piles unless provision is made for loading it out quickly in case of spontaneous combustion.

Comments:

“Yes; very important.”

“Would suggest that something be said in regard to breaks in piles where large quantities of coal are stored, so that if one section of the pile fires the entire tonnage would not have to be moved.”

“A pile of coal will give several weeks’ warning of an impending fire.”

“We always leave sufficient room near our storage piles to enable us by means of a scraper run by a motor to turn over such parts of the pile as show to be heating. This is the only way we have been able to successfully fight heating in coal piles.”

24. Since moisture from below assists spontaneous combustion the storage pile should rest on a dry base.

Comments:

“Yes, in case of dry storage.”

“Snow or rain on the pile and then covered is very dangerous, particularly snow.”

“Have not observed this, but if true, moisture is driven off before ignition.”

“Remove all refuse and provide drainage.”

“Fires do not originate at the base.”

“With some coal.”

“Do not find that moisture at base changes situation.”

“Our conditions are such that we cannot determine the effect of water on the bottom of the storage pile. We have found an equal number of fires twenty feet from the water and this would make it approximately thirty feet from the top of the pile. We do not believe that the fire originates on account of water at base of piles.”

“Questionable; some store part under water, part above.”

“Becomes saturated at base, evidently where fire always starts.”

25. Since a small amount of water seems to aid spontaneous combustion, the drier the coal is when stored and during storage, the less is the liability to spontaneous combustion.

Comments:

“I do not have the experience permitting me to question this but it looks doubtful as the chemical actions of moistening cannot take place once the hydration is completed. However, dehydration may later enable oxidation to act on the coal.”

“Generally yes.”

“Is this based on theory or experiment?” (An opinion expressed generally in the discussions of the International Railway Fuel Association).

“Doubtful.”

“Possibly.”

“When I was fleet engineer of the Pacific Station, about ten years ago, I used to have the colliers take on their loads with several lines of hose playing into the holds. I acted on the principle that, while a small quantity of moisture might

do harm, a liberal wetting would be a good thing. The scheme appeared to work all right."

Experiments by the U. S. Bureau of Mines show a lack of uniformity in the action of coals toward oxygen in the presence of moisture. In one case the dry coal oxidizes faster and in another case the moist coal oxidizes faster; also conflicting results have been obtained by different investigators.

Cause of Fires Other Than Spontaneous Combustion

26. Do not allow pieces of wood, greasy waste or other easily combustible material to be mixed with the coal during storage since they may form a starting point for a fire.

Comments:

"Unable to control usually."

"I have never observed this. Pieces of wood have no apparent effect, and I doubt that waste saturated with mineral oil would make any difference."

"Also avoid irregularities in structure of walls and floors such as angles and pockets."

"Almost invariably have found this the cause of our fires in the coal piles. In other cases the fires have started near trestle post or stubbing piles."

"Greasy waste buried in coal will invariably fire."

"Very important. Consider this most important."

"From my observation this is the most frequent cause of fires if the facts were known. Should be made clear that when a fire is once started it cannot be classed as spontaneous combustion. Subject to be divided: (1) Prevention of cause of spontaneous combustion. (2) Handling of fire when once started."

27. Avoid contact between the coal and all such external sources of heat as steam pipes.

Comments:

"My several experiences with fires in bunkers on board naval vessels were in each case associated with a hot steam pipe or bulkhead heated by proximity to steam boilers."

"Yes; either live or exhaust or over poorly installed exhaust lines which rust out and allow moisture and heat to reach pile."

"Most emphatically."

28. Pile coal as uniformly as possible and do not allow the lumps to roll to the bottom or to one side of the pile and thus form a flue for the entrance of air to the interior of the pile.

Comments:

"Impossible to prevent the lumps rolling to the bottom of the pile."

"The coarser the coal, the greater the voids through which air may enter."

"Seems desirable. Not practicable in our case."

"Hardly practicable."

"Impracticable."

"We aim to keep the bulkheads fairly high."

"Cannot be avoided."

"Cannot be helped in high piles."

"Inconsistent. Universal ventilation is a good thing."

"Rather impracticable for a railroad to do this. Let the air in, so that any heat generated will be carried off."

"Very important."

"Difficult to comply with, as regardless of the manner in which the coal is unloaded lumps will roll to the bottom and sides of the pile. If lump or egg coal is stored, this is not likely to cause trouble."

"Most important."

29. Avoid air channels in a coal pile such as occur about inbedded pipes, the bents of trestles, cracks through bulkheads, etc., since fires frequently originate near such air channels.

Comments:

"Never had this trouble."

"Believe ventilating the thing after removing the heating."

"Are you sure that nails in the bents are without blame?"

"Have used pipes to permit circulation of air. Feel that this has done some good toward preventing spontaneous combustion."

"We have always used old boiler flues in storage piles in order to ascertain the temperature by hanging thermometers in them or by noting the haze which is visible on cold mornings and indicates heating."

"Inconsistent. Universal ventilation is a good thing."

"This also provides ventilation which will prevent firing."

"Wooden bents of trestles and other wood, partitions, etc., furnish an easily oxidizable substance."

"Our methods of preventing spontaneous combustion are principally as follows: The maintaining of a 25-foot bulkhead all around the two piles; one containing 250,000 tons of high volatile and the other 150,000 tons of low volatile coals. When coal is received early in the season it is stored so that it can be used first; or in other words, our object is to use the oldest coal first."

"Protect the pile by bulkheads or walls. My storage contains December 1, generally 200,000 tons, 225 feet wide, 40 feet high. On the east and west sides concrete walls 13 feet high protect the pile. The north and south ends are open. Our fires, when we had them, a few years ago always were on the north and south sides of the piles, never on the east and west sides."

Method of Piling Coal

30. Unless coal can be piled so that air can thoroughly circulate through the pile and thus carry off the heat as rapidly as it is generated (this is very difficult to accomplish), the more closely fine coal is piled to exclude air the better.

Comments:

"I have always believed that tight packing of coal through pressure produced heat."

"It is impossible to carry off the heat generated in fine coal by any circulation of air."

"I think it is impossible to pile coal so closely as to exclude air to any beneficial extent."

"Inconsistent. Universal ventilation is a good thing."

"Coal must be piled low enough so that the generated heat can be carried off without reaching the firing temperature."

"To be dispensed with by favoring the subaqueous storage and is the only manner in which fine coal can be stored without hazard from spontaneous combustion."

"Since the voids in fine coal of uniform size are about the same as the voids in coarse coal of uniform size, would it not be better to say mixtures of various sizes tend to reduce the void spaces and exclude air?"

*Ventilation of Coal Piles**

31. Ventilation of coal piles by means of pipes running through the pile has usually not been successful in preventing spontaneous combustion, because the air does not circulate freely throughout the pile and in some cases the air currents through these pipes seem to be starting points for fires."

Comments:

"Several years ago, we were storing quite a large amount of Oklahoma mine run coal at Smithville, a coaling station which is located not far from San Antonio. I experimented with one pile of coal by placing a six-inch glazed tile on the bottom and running it the entire length of the pile. This tile was the ordinary bell shaped and in putting it together we used no cement, but just laid the ends together. Along the side of this pile of coal I stored an equal quantity without using any tile. The result was that in the pile where I had placed the tiling, we had no fire whatever, but in the other pile where we had no tile we experienced considerable amount of trouble by reason of spontaneous combustion. I am of opinion that pipes or flues do not always produce the desired results."

"Ventilation by means of pipes has not been successful. Do not think these pipes are the starting points for fires."

"Helps some."

"Heartily agree; think there has been a lot of misinformation put forth on this point."

"Have had no trouble with pipes. We think tendency is to carry away heat by radiation."

"Such pipes are probably useless except to indicate or follow rise of temperature."

"In two plants we have put in iron pipes to admit air but in the other where at least 12,000 tons are under storage, we have not taken measures to prevent

* See page 32, for extended discussion of coal pile ventilation by J. B. Porter.

heating. I am of the opinion that we have as good results where no measures are taken as where we have the air pipes."

"My personal opinion is that a cooling system employing extra heavy iron pipe and circulating water would be more satisfactory and certainly much safer, than any ventilating system that could be devised."

32. The great objection to ventilating systems is that they interfere with the handling of the coal.

Comments:

"Very expensive."

"They do not pay for the efforts."

"Unless thorough not of much benefit."

"Great objection is that they do not work as intended."

33. There is great difference of opinion in regard to the height of piles in which coal may be stored safely. Coal seems to fire almost as quickly in low piles as in high and as often near the top or outside of a high pile as near the bottom. The principal disadvantage of high piles is that coal in them cannot be so readily removed.

Comments:

"I have always believed that the higher the coal is piled the more liability to fire through pressure."

"Height undoubtedly varies for every coal but for any coal low piles are safer and definite height can be established for any coal. Low piles lessen heat from pressure and make for safety."

"It is not our experience that coal fires as quickly in low piles as in high. It has been our experience that if the depth of the coal is limited to twelve feet no fires will occur."

"After eight or ten feet there is no additional hazard because of increased height, and any increase of height within reach of the crane is not attended by an inconvenience in reloading the coal."

"If piled by hand piles should not be over ten to twenty feet wide, fifty feet long, though bottom of piles may touch. More space is required but it is safer. Piles may be much larger if mechanical handling is used."

"High piles due to the greater pressure fired more readily than low piles."

"Depends on the storage system."

"Think height should be limited to ten feet."

"We pile from twelve to fourteen feet."

"Believe in low piles about eighteen feet high."

"The lower the pile the less liability to fire."

"High piles give more trouble."

"Think height is important factor, the greater pressure inducing heat."

"Coal almost always fires near the bottom."

"Height for safety depends on the kind of coal."

"More fires from higher piles."

"If space is available pile low."

"Height of pile of no consequence, excepting crushing effect."

"Height of pile is one of determining factors. Have proved this, this summer."

"Depends entirely on method of storing. Low piles for hand, high for crane bucket."

"Might be amended to the effect that the height to which coal is piled should be regulated to conform to the facilities for removing or reloading the coals from the piles."

"Coal fires at the depth where enough air cannot penetrate and all of heat is not lost by convection to the atmosphere. This depth varies with the character of the coal."

"We limit the height of piles to twelve feet and have had less difficulty from spontaneous combustion in low piles. Furthermore if piles are narrow, they are easier to handle in case of spontaneous combustion."

Use of Water in Extinguishing Fires

34. Water is not generally successfully applied in extinguishing fire in a coal pile, because it is impossible thoroughly to saturate the pile. A small amount seems to aid spontaneous combustion.

Comments:

"Nearly all bituminous coals contain considerable tarry matter which is distilled from the coals during the heating process before the coal actually ignites. These tar vapors rise and condense in the cooler coal above forming a crust of mixed tar, pitch and coal which water will not penetrate and therefore the fire cannot be reached by water from the top except possibly in spots."

"We have extinguished several fires by applying water, cooling the coal for a distance of four or five feet, shoveling out the wet coal, then applying more water, cool another layer and shoveling that out and so on until we reach the point where the coal is either on fire or very hot."

"This is not our experience. Have an 8-inch water line along the field 1300 feet long and extinguish fire successfully with water."

"Water is effective when applied directly to the fire after removal of super-imposed coal."

"We expose the heated coal to the air which reduces the temperature and extinguishes fire."

"This agrees with our experience."

"Depends on size of fire."

"After getting to spot that is on fire water has to be used."

"Fire must be dug out."

"Whenever I had trouble with a bunker fire on board ship I simply opened one of the deck scuttles and let in a hose until the compartment was fairly well filled with sea water. This appeared to be an easy and sure way of overcoming the fire."

"Heated portion of pile can be cut off frequently by driving spray pipes into pile and flooding pile with water from fire hose connections which will retard fire and put it out sometimes."

Under-water Storage

35. The deterioration in coal stored under water is negligible. Such coal absorbs little extra moisture.

Comments:

“Coal when stored under water absorbs considerable moisture, and in fact, becomes so wet that it is necessary for us to lengthen the coking time.”

“Only place to store slack or nut.”

36. With under-water storage if the entire coal pile is not covered, the part of the pile above the water line is liable to spontaneous combustion.

Comments:

“We would not suppose that submerging part of a pile would render the remainder immune, neither would we suppose that the exposed part would be more liable to fire.”

“This liability is less than that with dry storage of depth equal to depth above water line. Believe the only practicable and reliable plan of storage to be with partial submergence. By this plan coal may be successfully piled twenty-three feet above the water line.”

“Very readily. I assume capillary action and wetting of the pile.”

37. The white coating on the outside of some coal piles is very thin and does not affect the value of the stored coal.

Comments:

“If not sold on looks as is often the case.”

“Not appreciably.”

38. The best method of handling coal in danger of firing is to load it out and scatter it so that it will be thoroughly cooled off.

Comments:

“If handy to point of consumption it can be put on the engine tank or boiler house coal bin for immediate use after being thoroughly wet down. This will save the expense of rehandling.”

“A uniform depth of four feet would probably not fire, and if a pile which contains fire were spread out to this depth, the fire could be extinguished with hose after which the coal, if not piled up again, would be safe.”

“Does not always work with Mid-West coal.”

“Turning pile over slowly will answer.”

“If the scattered coal is well thinned out, water should be put on it. Handled 7,000 ton pile of screenings this way this summer.”

39. Coal which has a tendency to spontaneous combustion should be turned over to keep down the temperature, although this causes an increase in breakage.

Comments:

"Impracticable for railroads."

"This would probably be effective, although expensive. It need not be resorted to until the coal begins to gas.

"Yes, but makes the expense of storing coal prohibitive."

"Do not disturb a pile at all once a pile has heated. It cannot be again stored."

"Not necessary until heating commences."

"Impracticable."

"Bad practice for Mid-West coal."

"Does not seem practicable for if the pile is a large one, say of 50,000 tons, the cost of turning it over frequently would be prohibitive."

"This conclusion and the one following seem to be inconsistent with each other."

"Pile it low enough this will not need to be done. No experience turning coal over."

"And soaked with water."

"Questionable."

"Yes, but once in six weeks or two months is often sufficient."

"Seems to indicate unusual difficulties in connection with storing coal and I am sure no one would undertake to store coal if it had to be turned over or moved frequently."

"On the Lake docks it is a common practice to move to another part of the dock, or to turn over a pile that begins to heat and which cannot be shipped out at once. This practice is diametrically contrary to the conclusion reached at one of the largest known storage plants for fuel coal.

40. If possible, stored coal should not be moved until it is to be used, unless it is heating, since piles which have apparently been safe have taken fire when opened to the air and the coal moved elsewhere, probably because of the opening up of new faces for oxidation.

Comments:

"Doubtful."

"Cut out unless it is heating."

"This looks doubtful; still I would leave it alone unless the temperature reaches the danger point about 150 degrees F."

- 41 Coal which has once heated and cooled is not subject to the same oxidizing processes as fresh coal.

Comments:

"Not if it has heated long enough."

"Never."

"Not to the same extent, but nevertheless coal that has been scattered and thought to be cooled has fired."

"One trouble is disintegration of shale seam or thin laminations of dirt and the pieces break up with handling or in firebox."

“Coal once heated has very little value for fuel purposes.”

“One of our mechanical engineers, W. L. DeBaufre, for about five successive years tested Pocahontas coal which had been stored at the New London, Conn., Naval Station in three different ways, namely, one part was stored under water, one part was stored on shore under cover, and the remainder was stored on shore not under cover. The test showed about the same evaporative value for each of these coals. If there was any difference it was in favor of the coal stored in the open, and the coal stored under water ranked next. Out at Cavite, in the Philippine Islands, the Navy Department has had considerable trouble with spontaneous ignition of its coal piles; but of course out there the sun is very hot and the days are long. Here at the Experiment Station we store our coal about twelve feet high on a concrete pavement, and so far we have had no trouble.”

“Practical railroad man hates storage coal. It is usually used the coldest season of the year when mines will barely produce enough steam; therefore, an 85 per cent storage results in only 50 per cent good service.”

“Our trouble is disintegration of shale or their laminations of dirt and the pieces of coal break up with such handling and in the firebox.”

42. Coal which has been in storage is considered by many to burn less freely when fired in a furnace, but this is largely prejudice and can be overcome by keeping a thinner bed on the grate than with fresh coal and by regulating the draft.

Comments:

“It seems to us that the ingredients which would promote spontaneous combustion must also act as agents to promote free burning.”

“Have found fresh-mined coal always gives best results. It is proved that even coal mined from the pillars in mines is very inferior to coal taken from the rooms.”

“It is usually claimed that heat units are less. Never heard of it burning less freely.”

“We like a slow-burning coking coal.”

“No material effect.”

“Nothing in this.”

“Coal frequently loses twenty per cent efficiency.”

“Should be saturated with water.”

“Actual experience indicates otherwise.”

“Due to absence of volatile.”

“Would burn less freely according to previous conclusion.”

“If volatile matter has diminished coal will not burn as freely.”

“We have more trouble the longer stored.”

“Not entirely prejudice. I believe it does not have the affinity for oxygen that fresh coal has.”

“We see no apparent difference.”

43. The decrease in heating value as a result of storing coal is small unless the coal has heated up sufficiently to decompose the coal or to drive off the volatile ingredients and the loss of moisture from the coal may increase the heating power per pound of coal.

Comments:

"Yes, depending on the length of time coal has laid in storage."

"Never had this experience. Degradation first, then loss of volatile pulls down the value."

"Our coal takes on moisture from storage."

"But not of the original pound."

"High burning rate on locomotives makes loss greater."

"Disintegration disturbs firing method on account of varying percentages of sizes in boiler house, coal bin and in firebox."

"This is a very debatable question and while tests show very little decrease in the thermal value in the coal during storage, the fact remains that for a given pumpage of water, our coal consumption has increased by amounts varying from ten to sixteen per cent. The coal has lost its shiny appearance and as a considerable portion of the volatile is lost, it does not act the same in our stokers as when freshly mined."

"We find that by wetting the coal that has been in storage for some time, its burning properties have been enhanced, especially so in the case of smokeless coals."

44. The coking properties of eastern bituminous coals are not materially affected by storing unless the coal heats, but the coking properties of Illinois and other Middle West coals are seriously affected or destroyed by storage.

Comments:

"As to the deterioration of coking properties in eastern coals, will say that some of them deteriorate rapidly while others do not. Eastern Kentucky is a marked instance of a coal that does not deteriorate very rapidly. The coking properties of Illinois and middle west coals are seriously affected."

"From conversation with by-product coking men, I gathered the opinion that the coking properties of all bituminous coals, including the Eastern, was affected by storage. Some coals to a greater extent than others."

"Have not noticed coking properties of Illinois coal to be affected by storage. We have about 15,000 tons in stock now and are using some that has been in stock over six months with no bad effect."

"Omit the phrase 'or destroyed by storage.'"

"Yes, for eastern coals. No experience Illinois coal."

"Gradual absorption of oxygen by coal does slightly decrease its coking ability, even though the coal does not heat seriously, particularly true with western coals."

"It is said by many practical coke men that coking quality is generally impaired by long storage of the coal. It is claimed by many coke oven operators that weathering of some coal affects the contracting qualities of the coal during the coking and, therefore, a stored coal is more likely to stick in the coke oven. By-product yields, especially that of the gas, are probably lowered in a high volatile coal by long storage."

45. The best preventive of loss in coal storage is the constant inspection and

watching of the coal for incipient heating and immediate removal of coal from the spot affected.

Comments:

"Isolated hot spots sometimes occur which can be readily dug out with a crane, leaving the remainder of the coal in good condition. The temperature of every pile will go up and down, influenced in part by the temperature of the surrounding air and in part by internal heating, but it would be inexpedient to disturb the pile unless the temperature rises to near 200 degrees and is accompanied by the evolution of gas."

"Best preventive is properly storing it. Know your coal and store it low enough so that it will not fire. An inverted V-shape pile is preferable."

"Proper selection of storage space, sizes stored, properly seasoned coal, manner of handling. Do not store mine run under any conditions and especially do not build up pile by carrying track upon pile. Recent experience of the Big Four shows that fire is sure to follow such methods."

"The real successful method of storing coal in this locality, Springfield, Illinois, has been under water. When piled on the ground should be in long piles with quantity limited as much as practicable. Would recommend only storage of screenings of fine coal and when this is done the only successful method has been under water."

"Place 1½-inch pipes every sixty feet in pile and take interior temperature every 36-48 hours by lowering thermometer floating in mercury down the pipe, leaving it in the pile for about ten minutes. On large storage a mercury electric alarm system will pay."

"Give suggestions as to manner of "inspection and watching; i. e., should thermometer holes be built in piles for inserting thermometers in center of piles? What rise in temperature is considered dangerous? Examination of gases? Odors from pile?"

46. Other Suggestions.

Comments:

"Use coal from the newer piles."

"Coal successfully stored for a year is usually past danger."

"No chemicals applied as for extinguishing other fires have any more effect than water (which is very little). The thing to do is dig into the fire and move the coal as quickly as possible."

"Successful storage depends on proper selection of storage space, sizes stored, storage of properly seasoned coal, and manner of handling. Do not store mine run under any conditions and especially do not build up pile by carrying track on pile, as recent experience of railroads shows that fire is sure to follow such practice."

Through the courtesy of Frank Haas, Consulting Engineer, Consolidation Coal Company, the following conclusions of that company regarding coal storage are given:

(1) "Spontaneous combustion is not limited nor is the tendency greater

with any one class of coal—referring now only to the bituminous coals ranging from sixteen to forty in volatile matter.

(2) “The tendency is not in proportion to the quantity of sulphide present.

(3) “In coals of the same kind (graded according to volatile matter) those which have the highest per cent of impurity are more liable to spontaneous combustion.

(4) “In coals of the same kind, heating is more liable to occur in the fines.

(5) “Weather conditions apparently have no effect (in this it should be explained that our records do show more on cold and wet days, but we have assumed for good reason that heating is more readily observed on such days).

(6) “The coals with which we are familiar have never been known to fire inside the mines, either in the solid or in accumulations inside the mine.

(7) “In stored coal quantity or depth of pile have evidently not much to do with it as we have found local heating to occur near the top as well as in the center or bottom of the pile.

(8) “In our opinion, and we have numerous cases to substantiate it, a great number of local heating cases have been due to waste material brought out with the coal, such as pieces of wood, discarded clothing saturated with miners oil, waste, brattice cloth, etc. We do not hold exclusively to this for there still remains to be explained the slow propagation at a temperature far below that of normal combustion temperature of coal.

(9) “We have many instances showing that more local heatings have occurred than were discovered, showing very small areas of activity and were spontaneously extinguished, indicating that propagation of heat is not inherent in average coal, but localized by some particular, perhaps foreign, condition.”

APPENDIX III

EXPERIENCES OF FIRMS AND INDIVIDUALS STORING COAL

MANY of the answers to the questionnaire sent to coal dealers and users have been incorporated in the preceding pages of general discussion, but there still remain a few specific instances of successful and unsuccessful attempts to store coals of many different kinds under various conditions which have not been discussed. Available information relating to these cases is presented in the following paragraphs. In each case a brief statement of the conditions is given and while a certain amount of repetition is thus unavoidable, this method of presentation seems desirable for purposes of comparison.

42. *Storage for Domestic Use and by Coal Dealers.*—Personal interviews with coal dealers in Urbana and Champaign and answers received to the questionnaire indicate that there is no trouble in storing coal under the conditions which prevail in the ordinary coal yards and in dwelling houses. The loss from breakage in storing and reclaiming bituminous coal is 5 per cent or more, according to the coal and the method of handling. There is no loss in fuel value and consequently stored coal sells for the same price as fresh coal, although there may be a slight loss of weight due to drying out.

The Crystal Ice and Fuel Company* of Danville, Illinois, stores coal from Harrisburg, Illinois, and from the No. 4 vein in Indiana during July and August, when the coal is cheapest and driest, in 65-ton covered bins with plank floors. The period of storage is three months. The sizes are kept separate and the slack is not removed before storing. The coal is stocked by dumping and reclaimed by shoveling at a total cost of seventeen cents per ton.

D. G. Porter, of the Rock Island Fuel Company, stores about 8,000 tons of 1¼-inch washed coal from Springfield, Illinois. The coal is placed on the ground by hand and in continuous flat top piles eight feet high, at a cost of eight cents per ton for stocking and ten cents for reclaiming. It is kept in storage for six months with no decrease in heating value unless the pile heats. The coal is stored in November and December to take advantage of cold weather so that the snow and ice will stay in the coal until late in the spring. The coal thus stored does not ordinarily heat for six months, but if heating does occur, it is loaded out and burned.

The Beck Coal and Lumber Company of Harvey, Illinois, stores about 500 tons of Pocahontas coal and 700 tons of Illinois coal for five or six months, the sizes being kept separate and slack being removed before storing. It is stored from fourteen to thirty days after mining and preferably in June, July, and August. There is no difference in the selling price of stored and fresh coal and no depreciation from heating occurs, but there is a loss of from two to eight per cent from breakage. If heating occurs the coal is moved. It is stored on the ground in bins from eight to ten feet high and reloaded by hand shoveling. The expense of unloading, storing, and reclaiming is 27.82 cents per ton.

* Thomas Corsey, Secretary.

O. S. Dodge and Sons, Incorporated, of Monroe, Wisconsin, store 1,200 tons which are mostly two inches by three inches nut coal from Franklin County, Illinois. It is stored in bins by elevators and run out by gravity. The different sizes are kept separate but the slack is not removed. There is no decrease in heating value, but a considerable loss through breakage.

The Davenport Locomotive Works, Davenport, Iowa, report that 300 tons of 2-inch screenings from Franklin County, Illinois, are kept in storage on the ground in a continuous pile ten feet high, from three to six months with slight undetermined loss in heating value and no firing.

French and Hecht, of Davenport, Iowa, stored washed Illinois pea coal in large quantities, either under cover or in the open without any firing, but they report that they always have trouble from fires in attempting to store unwashed screenings.

The H. A. Hillmer Company of Freeport, Illinois, stores from 1500 to 2000 tons of West Virginia egg, and Illinois and Kentucky lump and nut sizes on cement floors in a coal elevator in which there are five compartments thirty feet by thirty feet by fifteen feet, the coal being piled from ten to thirty feet high. It is stored and reclaimed by wheelbarrow and conveyor and if carefully handled there is little breakage. From five to fifteen days elapse between mining and storing and it is kept in storage six months, the sizes being kept separate. The slack is not removed and coal is preferably stored in April and May, because then the price is usually fifty cents less per ton than in other months, and since the year's domestic business is about closed a force of men is available which may be employed in unloading the coal. The weather, moreover, is not too hot, whereas in July and August it is almost impossible to get men to unload coal. There is no difference in the selling price and no deterioration, for if the coal is kept under cover and dry there will be no heating, but if heating occurs the coal is removed and wet down. The expense of storage is not kept.

I. C. Cuviller, publisher of *The Coal Trade*, Minneapolis, Minnesota, summarizes the storage problem for the city and coal trade as follows:

In the domestic trade lump, egg and No. 1 nut from Williamson, Franklin and Saline counties are stored out of doors mainly on the ground in round pyramidal piles of varying heights, about three weeks after being mined, and the coal usually is kept in storage from July to October. The sizes are separated and the duff removed. May, June, July, and August are considered the best months in which to store since the price is from 50 to 75 cents lower than at other seasons. There is no decrease in value and no difference in price of stored and fresh coal. The loss in breakage is thought to be about five per cent. Small amounts are usually stored in bins and fires are not common. When eastern coal is stored in large piles, it fires and the piles must be worked over and spread out. This is done usually by means of wheelbarrows but conveyors are being installed.

The Joseph Schlitz Brewing Company of Milwaukee stores West Virginia and Western Pennsylvania coals in continuous pyramidal piles fifteen feet high on a wooden floor with concrete walls during the season of lake navigation. There is little loss in heating value, and breakage is negligible since the coal is crushed

for use in stokers. The company does not buy high sulphur nor friable coals because of the tendency of such coal to heat.

Crerar Clinch and Company* of Chicago keeps in storage, if possible, about 15,000 tons of egg and nut, Nos. 2, 3, 4, and 5, washed and screened coal from Macoupin, Perry, and Jackson counties, Illinois. The coal is screened before storing and is placed in storage from one to two weeks after mining. Most of it is stored in July and August. The coal is used for steam purposes and there is no financial advantage in storing, the only difference in selling price being the added expense of storing. The coal is stored and reclaimed by hand or by a crane. It is stored on a plank floor in conical piles about sixteen feet high, and the sizes are kept separate. The coal is thought to decrease in heating value about five per cent and the large sizes to lose about ten per cent through breakage. The stored coal which has considerable sulphur in it heats within two or three weeks. No precautions against heating are taken except to store in dry weather, and if heating occurs to turn the coal over or use it. It is estimated to cost twenty-five cents per ton to store and reclaim.

The Ebner Ice and Cold Storage Company†, Vincennes, Indiana, keeps in storage several thousand tons of 1¼-inch screenings from Fort Branch, Indiana, Wheatland, Knox County, Indiana, and Clinton County, Illinois. This coal is placed in a concrete pit arranged so that it may be flooded in a short time if it heats. A small amount of coal is also kept in storage on the ground. The coal is dumped from a trestle into a pit and is reclaimed by a bucket conveyor. The expenses are as follows:

	Storing	Reclaiming
Labor	\$0.04	\$0.10
Depreciation on mechanical equipment . . .	0.03	0.03
Interest on investment	0.084	0.084
Total	\$0.154	\$0.214

The Polar Wave Ice and Fuel Company‡, St. Louis, Missouri, stores 20,000 tons of screened lump coal from St. Clair and Williamson counties, Illinois. All the lump coal is forked into storage, the sizes being kept separate. It is stored within one or two weeks after being mined and is kept in storage from a few weeks to several years. It is stored during the dry summer months, when possible, and there is a slight decrease in heating value and a loss of from ten to fifteen per cent from breakage. Heating is more likely to occur in the open than under cover. Dried lump coal forked into a shed seldom heats, but wet coal will heat in time. It is stored by means of especially constructed chutes traveling on a trolley and by wheelbarrows, and is reclaimed by hand. It is usually placed on a brick or concrete floor in piles, about 10 feet high and from 30 to 60 feet wide, parallel with a railroad track.

* A. R. Stooper, Yard Superintendent.

† C. B. Wissing, Superintendent.

‡ John C. Muckerman, Vice-President.

The expense of storage is as follows:

	Storing	Reclaiming
Overhead	\$0.05	\$0.05
Labor	.20	.10
Supplies	.02	.01
Depreciation on mechanical equipment and S. S.	.07	....
Interest on investment and coal	.12	....
Insurance or equipment and sheds	.01	....
Insurance on coal	.01	....
Total	\$0.48	\$0.16

In September, 1914, run of mine coal in the bin of the new high school in Urbana, Illinois, ignited and considerable difficulty was experienced in extinguishing the fire. The bin is 56 feet long, 12 feet wide, and 12 feet deep fed through two top holes. The walls are of brick, 8 inches thick, laid in plaster with about eight inches of air space between the storage bin and the wall enclosing the boilers. The coal stored was from Seam No. 6 from central Illinois and 200 tons of run of mine were placed in the bin within a few days after it was mined, the coal being wet down sufficiently to lay the dust as it was stored. The only separation of sizes was that due to the large lumps rolling down the sides of the cones while the fine coal formed the centers. The last load was placed in the bins June 29 and five weeks later the coal was discovered to be on fire. The top charging holes and the bin door were covered as tightly as possible with tar paper, and CO₂ gas was run into the bin which was then not opened until November 5. Two days after opening fire was again discovered. After partially flooding of the bin proved ineffectual, part of the coal was removed so that a hose could be played on the fire from the inside, but this plan did not prove effective and the heated coal was shoveled out. Similar trouble was experienced during the following winter, but since that time the practice of wetting down the coal when placed in the bin has been discontinued and an effort made to store only lump coal. Since this practice was adopted no trouble has been experienced.

A similar fire occurred in the bunkers of the Champaign, Illinois, high school, where 500 tons of central Illinois coal were stored in May, 1917, the coal containing considerable fines and the upper part of the pile being wet down when it was loaded into the wagons to be hauled to the bins. Toward the end of October smoke was discovered coming from the pile, which was then wet thoroughly by the fire department. About 20 tons were loaded out from the top of the pile and a hot spot found from four to five feet from the top. The surrounding coal was then taken out and no further trouble has been experienced.

The Northwestern Fuel Company*, St. Paul, Minnesota, stores, 50,000 tons of West Virginia and Maryland lump, egg, nut, and run of mine and one million tons, or more, of Pennsylvania, Ohio, West Virginia, and Kentucky lump, run of mine and screenings. Slack is sometimes removed at the mines, but not at the

* G. H. Hutchinson, Chief Engineer.

dock, and sizes are kept separate in storage when they are so delivered to the dock. There is thought to be a slight decrease in heating value and a loss from breakage which varies widely with the conditions of handling. If the bituminous coal heats, it is usually within one to six months, according to the kind, character, and size of coal. To prevent heating, the coal is shipped out as promptly as possible, or if heating occurs, it is moved by a clam-shell bucket and bridge. The loss through heating varies from slight to complete destruction according to the extent of the heating. The coal is stored on a plank floor, which is laid on sand filling. It is placed in continuous piles from 33 to 55 feet high. If possible, the coal is piled to prevent large sizes rolling to the bottom. There are from 20 to 75 per cent fines below $\frac{3}{4}$ inches when the coal is stored.

The Consumers' Company* of Chicago stores 250,000 tons or more of bituminous coal and a similar amount of anthracite, the bituminous being mainly Illinois and Indiana coal larger than the No. 4 washed. Some Pocahontas mine run is also stored. At times, portions of the stored coal are not moved for several years. In the larger bituminous storage yards, the coal is stored by a locomotive crane and grab bucket. The plat of Yard 150 (Fig. 58) shows a typical storage yard. The coal is stored about 26 feet high in piles, the shape of which depends upon the shape of the available storage space. The expense of handling depends upon conditions. Ordinarily, the coal is not insured against fire.

The experience of the Consumers' Company is that screenings below $1\frac{1}{4}$ inches in size will fire and that size No. 5 washed coal will fire even more readily than screenings, but that sized coal above $1\frac{1}{4}$ inches from which the duff has been removed will, in general, stock without firing. Firing will start more quickly if wood is present. The leg of a trestle or a similar piece of wood will act as a flue and firing is likely to start near any such wood imbedded in the coal pile. High sulphur coals are thought to fire more readily than others. Ample flooding with water will put out a fire, but a small amount will accelerate the fire, and the best way is to turn over the pile.

The St. Bernard Mining Company† of Nashville, Tennessee, stocks a great deal of $2\frac{1}{2}$ -inch bituminous lump coal in square piles on the ground to a height of 20 feet. The coal is stocked by dumping from wagons and is reclaimed by forking. The expense is ten cents per ton for labor and twelve cents for all other items, a total of twenty-two cents per ton. The coal is placed in storage from three to six days after being mined and remains in storage for about nine months. The best time for storing is said to be September and October, because then it is dry and cool. The coal is stored to protect contracts of the company and to insure a domestic supply. Storage is not profitable, but it is done as a precautionary measure. The coal stocked is to be used for steam and domestic purposes and there is no difference in the selling price of the fresh and stored coal. It is estimated that a loss of twenty-five per cent in breakage has resulted in storing and reclaiming. In 1900 the Company had a bad fire in its storage pile. The next year enough air shafts, which were 12 inches by 12 inches and of 2-inch oak, were placed around the posts, which supported the shed, and connected at the bottom by troughs to give circulation of air through the pile. Since that time,

* F. J. Hibbs, Superintendent of Construction.

† J. B. Love, Manager.

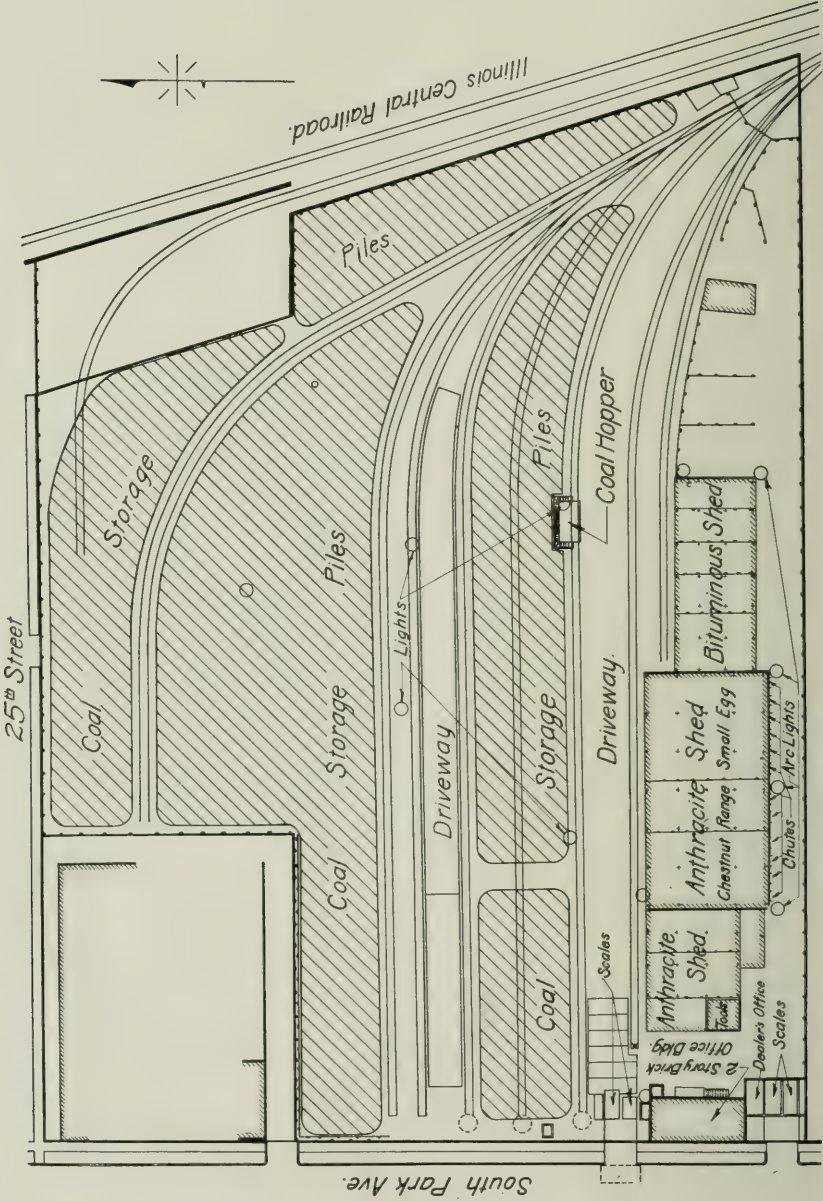


FIG. 58. TYPICAL STORAGE YARD OF THE CONSUMERS' COMPANY, CHICAGO

there have been no fires. Where the troughs rest flat on the ground, auger holes are bored to permit the air to circulate, but sometimes they are raised by blocks from two to four inches high to give circulation. As much as 8000 tons have been stored in this shed, but usually not more than 6000 tons. No fires have occurred since the flues were installed, but J. R. Love says:

“There might be some other reason for the fire that we had at the beginning of our operation as it started where we dumped the first coal, which had about a 20-foot drop and was badly broken and made a large amount of slack or dust. The next year, in addition to putting in the air shafts, we were very careful to build up the coal from the ground about 15 feet, so as to break the fall of the first coal that was dumped into the shed. I am not in a position to say for certain, whether the different method of handling the coal, or the air shafts, has kept us from having any hot coal after the first year.”

W. D. Langtry says in this connection:

“Recently I investigated a storage pile in Michigan at a plant which had the idea of putting down pipes for ventilation. In one instance there was one pipe that was a little taller than the balance, and I found by blowing some cigarette smoke over the top of the short pipe that this smoke was carried into the pipe by the draft, and the taller pipe was conducting the gases out of the pile and any smoke that was blown across its top was naturally conveyed up. It was plain to be seen that this was a current of air passing through the coal. If this was sufficient to keep the coal cool no trouble would occur, but from the gases being given off, I am afraid the air current was deficient.”

The Pittsburgh Plate Glass Company,* Crystal City, Missouri, stores 40,000 tons of mine run coal from Franklin and Williamson counties, Illinois, on the ground in continuous pyramidal piles twenty feet high without having the slack removed. A Browning clam-shell locomotive crane is used to store and reclaim the coal and the expense is said to be twenty-five cents to store and twenty-five cents to reclaim. Storage during the summer is considered the best. The coal is kept in storage from two to three years, with a slight decrease in heating value. The coal may heat at any time after storage, and if so it is moved to another place.

43. *Light, Heat and Power Companies.*—Public utility companies operate under the necessity of maintaining continuous service and are, therefore, vitally interested in the storage of coal. Many of these companies have already given considerable attention to the subject.

The Rockford Electric Company†, Rockford, Illinois, stores about 8,000 tons of 1½-inch screenings from Harrisburg, Illinois, on the ground in continuous pyramidal piles twenty feet high. The coal is placed in storage within about two weeks after being mined and is kept there for a period of six months. The coal may heat after two months and if so, it is turned over with a crane, but an effort is made to keep it from heating by ventilating with pipes. If the coal dries out and heats to any considerable extent, it is thought to deteriorate from twenty to fifty per cent. It is reported that it costs ten cents per ton to place it in storage and ten cents to reclaim it.

* E. C. Taylor, Superintendent.

† Adam Geschwindt, General Manager.

The Wisconsin Gas and Electric Company,* Racine, Wisconsin, stores 30,000 tons of washed mine run Youghiogheny coal in a continuous pyramidal pile thirty feet high. The coal is stored on the ground by means of a bridge and bucket at an expense of eight cents per ton for storing and twenty-two cents per ton for reclaiming. This includes labor, supplies, depreciation on mechanical equipment, interest on investment, and rental of the land on which coal is stored. An interval of three or four weeks elapses between mining and storing. The coal is used for making city gas and it is thought to suffer a slight deterioration in value for that purpose. It sometimes heats in from two to four months in which event it is quenched with water and worked over.

The United Railways Company† of St. Louis keeps in storage as much as 5,000 tons of central and western Illinois screenings and mine run. These sizes are kept separate in storage but the slack is not removed. The coal is stored in bins and in piles on the ground about ten feet high with a locomotive crane. It is placed in storage about three days after leaving the mines and is kept there about three months in hot weather. The financial advantage of storing is regarded as doubtful. The coal is used for power purposes and little deterioration in heating value is noted unless firing takes place. The lumps are said to break up, but at this plant the coal is crushed before firing. The coal frequently heats and the time of heating is said to depend on the nature of the coal and on the weather. When heating begins, the coal is, if possible, removed and used.

The Aurora, Elgin and Chicago Railroad Company‡ keeps in storage from 2,000 to 15,000 tons of coal from Franklin and Williamson counties, Illinois. The coal is stored on the ground in piles eighteen feet high, each pile containing about six hundred tons. This has been decided upon as a safe size of pile to avoid heating. The coal is stored with a crane and clam-shell bucket and is placed in storage about one week after being mined. The slack is not removed but the sizes are kept separate. The coal is kept in storage for periods as long as one year. Winter is regarded as the best time in which to store, but because of the availability and price of coal in the summer most of it is stored between July and September. The reason for storage is mainly to prevent a shortage, but there is also said to be a saving of from thirty to fifty cents per ton by storing in the summer. There is considered to be a differential of fifteen cents per ton in the selling price against stored coal, which is thought to decrease in heating value from ten to twenty per cent. It has been the experience of this company that coal high in sulphur is not suited to storing, but, if stored, should have the slack removed and should be screened. It is reported that low sulphur coal, such as the best from Franklin and Williamson counties, stores well in any size and does not heat or deteriorate to any considerable extent for a period of several months. Certain coals from the same field, however, have heated after less than a week in the bin. Gillette is convinced that the amount of sulphur in the coal is a determining factor in heating. He says:

“Some three years ago we had about 10,000 tons of Cuba screenings on the ground. This coal started to fire from the inside and before we were

* D. E. Callender, General Manager.

† W. E. Bryan, Superintendent.

‡ E. S. Gillette, Electrical and Mechanical Engineer.

able to pick it off the ground the majority of it had deteriorated about twenty to forty per cent in heat value, leaving some three cars of ashes which could not be run through the plant at all and consequently were a total loss. This coal had a high sulphur content.

"Since then we have piled our coal in small separate piles. We aim to put from twelve to sixteen cars in one pile. If we notice a fire starting in one of these piles, we immediately pick it up with a crane. Since we have started this system we have had practically no trouble from firing of our coal."

John Hunter, chief engineer of power plants, Union Light and Power Company, St. Louis, Missouri, says:

"For the past ten years the miners' and operators' agreement expired every two years, and anticipating a strike at such time our local industrial and central station plants usually protected themselves by storing coal for at least thirty days. In 1912 our company stored about 30,000 tons of coal, and I am enclosing herewith a photograph (Fig. 59) showing one of the piles of 25,000 tons of mine run from the Mt. Olive and Staunton mines in Madison County. The coal was stored in February and March and was entirely removed and used by June 1. It was laid on the pile by hand and the track raised as the height of the pile increased, and was reloaded with a steam shovel from the pile into cars. We paid the Litchfield and Madison Railroad Company ten cents per ton to pile the coal and an equal amount to reload it, and it is my understanding that this figure just about covered the actual expense. After the coal was reloaded it was immediately shipped to our power station at Ashley street in St. Louis, placed in our bunker and used up in fifteen days.

"We experienced two fires in this pile after it had been on the ground for two months. These fires were checked by working into the pile with our steam shovel and loading the coal in steel cars; about twenty cars in all were removed in this way.

"The coal generally used by our company is from the mines in Macoupin, Madison and St. Clair counties, ninety-five per cent of it being screenings. The only regular storage we have is in the coal bins directly over the boilers in the main central station. These bins have a capacity of 12,000 tons with an average operating storage of 7,000 tons. The bins are divided into eight sections, and it is necessary to have one of these bins working down for cleaning and reloading, otherwise extensive fires are very troublesome. The average temperature below these bunkers is about 125 degrees, and we find it impossible to carry the coal longer than two months, in other words, it is necessary to renew the coal in each of our bins every two months.

"In the fall of 1911 I personally knew of one of the mine operators in St. Clair County laying on the ground the screenings from their mines, about 30,000 tons in all, with the view of holding them in storage for the anticipated strike on April 1, 1912. However, in February of that year I examined this coal and found that over eighty per cent of it had burned, the

high percentage of sulphur, clay and other impurities being responsible for these fires.

"It is a common expression among the engineers in our locality who are handling coal that it is impossible to store any of the standard coals from the inner group of mines in Madison and St. Clair counties, this being my personal views, unless the coal is specially selected. By this I mean that no coal of less than six-inch sizing be laid on the ground."

W. E. Bryan, of the United Railways Company of St. Louis, says:

"We try to decrease our storage in hot weather on account of the dangerible to firing than other coals. It has also been our experience that coal which has been cleaned by washing, say of nut or pea size, will not fire so readily as the screenings containing so much dust. The hotter the weather, the more is the tendency to heat. Also wet weather in connection with sulphurous coal exposed to the air will cause heating especially when followed by hot weather.

"Three months is the average length of time coal is in storage at one plant, which has a regular storage house. We do not make any tests for heating and as a rule have no trouble if the coal is not stored more than three months. We have stored the coal longer than this without trouble, but we do not like to carry more coal than can be moved in three months.

"We try to decrease our storage in hot weather on account of the danger of firing and in the past have been stocking up to some extent in the fall when screenings are comparatively cheap. Under these conditions we may at times hold the coal in storage longer than three months.

"It is hard to give any definite figures because our results have varied quite a good deal."

The Laclede Gas Light Company* of St. Louis stores from 5,000 to 15,000 tons of Pocahontas screenings and from 40,000 to 85,000 tons of run of mine coal from Elkhorn, Kentucky. The sizes are not kept separate and slack is not removed before storing. It is stocked from seven to ten days after being mined and preferably in the spring or summer. No decrease in heating value is noted and there is no loss from breakage. The Pocahontas coal heats in about six months. To prevent heating the piles are turned over, but if heating occurs the pile is quenched with water and used as soon as possible. Heating causes a loss in gas and in by-products. The coal is stored by means of a locomotive crane and clam-shell bucket. It is similarly reclaimed directly from the pile. The coal is stored directly on the ground in long, continuous piles from twenty to forty feet high.

The Cleveland Illuminating Company keeps about 15,000 tons of slack, 85,000 tons of run of mine Ohio No. 8, western Pennsylvania, and Fairmont, West Virginia, coals in storage, the sizes being kept separate. The coal is stored by means of a gantry crane hoist in rectangular, continuous piles to a height of thirty-five feet and is recovered by means of a locomotive crane which handles about 500 tons in ten hours, the hoist handling about 1200 tons in ten hours.

The East St. Louis Light and Power Company stores from 5,000 to 12,000 tons of screenings under water from St. Clair and Madison counties, Illinois, as an

* J. F. Bulfin, Auditor.



FIG. 59. TWENTY-FIVE-THOUSAND-TON PILE OF RUN OF MINE COAL STORED BY THE
UNION LIGHT AND POWER COMPANY, ST. LOUIS, MISSOURI

emergency supply. There is no loss from breakage or depreciation in heating value.

44. *Storage at Metallurgical Plants.*—According to the latest reports of the U. S. Geological Survey, there are more retorts for smelting zinc in Illinois than in any other state. This number has gradually increased and much of the smelting of zinc formerly carried on in Kansas, owing to the presence of natural gas, has within a few years been transferred to Illinois on account of the adequate coal supply. It is of especial interest, therefore, to note to what extent coal is being stored at the zinc plants. The following is a resume of the answers given in response to the questionnaire sent to the ten zinc smelters in the State.

The Illinois Zinc Company at Peru and the Matthiessen and Hegeler Zinc Company at LaSalle operate their own mines contiguous to the smelters and do not store.

The Sandoval Zinc Company at Sandoval and the Missouri Zinc Company at Beckemeyer do not store coal.

The Collinsville Zinc Company at Collinsville stores No. 4 and No. 5 mixed Franklin County coal on the ground in continuous piles from ten to twelve feet high, in order to assure a supply for continuous operation. The coal is thought to decrease in heating value, but the amount of this decrease is not known. Coal is stored and reclaimed by hand, and no heating has been observed.

The American Zinc Lead and Smelting Company of St. Louis, at its plant in East St. Louis, keeps in storage on the ground from thirty to sixty days 200 cars of St. Clair County, Illinois, run of mine coal without removing the slack. Coal is unloaded by locomotive cranes upon conical piles ten feet high. Cranes are also used for reclaiming the coal and while the storage costs are not segregated, they are estimated to be twenty cents per ton for placing the coal in storage, and fifteen cents for reclaiming. These figures include interest on the investment, repairs of unloading machinery, and all charges. The coal is used for making producer-gas and is stored to insure a supply at all times, but no financial advantage is secured. The coal is thought to decrease in heating value from about five to ten per cent. No data are available concerning breakage. Some kinds of coal fire, the time of firing after storage depending on the size and the sulphur content of the coal. As soon as heating is noticed the coal is picked up and used. Little time elapses between mining and storing. Winter is considered the best time to store.

The Mineral Point Zinc Company at Depue, Illinois, stores coal in continuous piles from 600 to 700 feet long, 60 feet wide, 12 feet high, the piles being parallel with two tracks on which the locomotive crane and cars operate. The storage yard has a capacity of about 60,000 tons. Grab buckets are used and the expense of storing is from five to six cents and for reclaiming from five to six cents per ton for labor, materials, maintenance, and overhead. Coals principally from Harrisburg, Saline County, Illinois, are stored and they are kept in storage from six to twelve months. Lump or mine run is preferred. Screenings are kept in storage from one to three months, the different sizes being kept separate, but slack is not removed. The coal is stored in from five to ten days after being mined, mainly in the fall in anticipation of the spring needs but some coal is kept

in storage at all times to insure against strikes and transportation trouble. Coal used for fuel and gas making purposes is thought to deteriorate in heating value, but no definite data are available. Screenings from southern Illinois heat in about ninety days, those from the Peoria district in about twenty-five days. From 20,000 to 25,000 tons of mine run, lump, egg, and washed nut from the Peoria district are kept in storage at all times and no firing has occurred, although the piles are of the same size as those of the screenings. It is reported that a pile of Peoria run of mine has been in storage for a year without firing, the pile being twelve feet high, thirty-five feet at the base and containing about 3,000 tons.

J. H. Brooks, Superintendent of the Depue plant, says that the slack is sometimes received hot in the cars and he believes that while a shallow pile will help to prevent the firing of unwashed Illinois screenings to a certain extent, his experience is that this class of coal cannot be stored for an indefinite period on the ground. As soon as heating is discovered the coal is loaded out.

The Robert Lanyon Zinc and Acid Company* of Hillsboro, Illinois, stores about 2,000 tons of run of mine Montgomery County, Illinois, coal from which the slack has been removed. It is stored in five to seven days after being mined and is kept in storage from three to six months. The coal is used for steam and gas making purposes and is stored to insure supply, with no financial advantage resulting. It is thought to decrease two per cent in heating value and it sometimes fires in from one to nine months, the injury from firing depending upon the extent of the fire. Piles are continuous, fifty feet wide and five feet high, and are placed on the ground or preferably on cinders. To prevent firing the piles should be kept low.

45. *Storage for Coke Ovens and Blast Furnace Plants.*—The coal required for coke and blast furnace plants is so great that a considerable quantity is always kept in storage to meet emergencies. Storage also makes it possible to take advantage of lake transportation.

A number of coke and steel companies operating in the Chicago and St. Louis districts, and in other districts in the Middle West stores coals both from the Middle West and from the East.

The By-Products Coke Corporation† of South Chicago keeps in storage a maximum of about 400,000 tons of miscellaneous sizes of West Virginia coals made up of about 160,000 tons McDowell Big Sandy coal and 240,000 tons of Kingston coal from Fayette County. Coals of different varieties are separated, but no attempt is made to separate sizes. The coal is piled on a 4-inch timber flooring in pyramidal piles from forty to fifty feet high by means of a belt conveyor operated on movable bridges. It is reclaimed by buckets. The costs are not available since they are not segregated. Although the company stores large quantities of coal in the summer when lake transportation is open, it is considered best to store in the winter so that there may be less initial heat in the pile. In stocking an effort is made to avoid segregation of lumps in the pile. The coal is believed to deteriorate in heating value, but no data are available. After the coal is in storage four months, it is turned over to prevent heating. The coal some-

* R. M. Roosevelt, Manager.

† W. H. Allen, Superintendent of the Coke Plant.

times heats in from three weeks to three or four months in which event it is used up promptly or is turned over upon fresh piles.

The Inland Steel Company* stores at Indiana Harbor 70,000 tons of run of mine and slack coal from a district north of the Pocahontas region in West Virginia, and 140,000 tons of $\frac{3}{4}$ -inch Youghiogheny lump coal. The coal is stored from ten to fourteen days after mining. The slack is not removed and the sizes are not kept separate. The greater part is kept in storage from December 1 to April 15, while lake transportation is closed, and some remains in storage two or three months longer. It is stored on a 3-inch maple floor in a continuous pile forty feet high by means of a traveling bridge and belt conveyor. When the storage season opens, the floor is cleaned and coal is stored gradually from one end to the other of the pile. Coal is reclaimed by means of buckets, the coal longest in storage always being taken out first. August and September are considered the best months in which to store since the coal received then is dry. The heating value of the coal is not determined, but the gas made from the stored coal does not vary materially in heating value from that made from fresh coal. Coal sometimes heats and fires in from a few weeks and to prevent heating it is turned over occasionally. If heating occurs, the affected part is removed. Coal thus heating loses its coking qualities.

The Illinois Steel Company† keeps in storage at the Joliet Works from 10,000 to 30,000 tons run of mine Pocahontas and from 10,000 to 30,000 tons of coals from Letcher and Harlan counties, Kentucky. Coal is piled twelve feet deep by means of bridge and conveyor in concrete pits having concrete floors. It is stored within one or two weeks after mining and is kept in storage from one to twelve months. The coal may heat to a variable degree in from sixty to ninety days and and if heating occurs it is taken out of stock.

The Illinois Steel Company‡ also stores at South Chicago, Illinois, quantities as great as 100,000 tons of coal from McDowell County, West Virginia, and 100,000 tons from Letcher County, Kentucky. The grade is run of mine and the slack is not removed. The coal is stored in the summer and within two weeks after being mined. It is used to make by-product coke. Coal is stored in a concrete bin in continuous piles fifty feet high. It is stored and reclaimed by means of overhead bridges.

The Wisconsin Steel Company of South Chicago does not stock in large quantities and keeps only from 4,000 to 10,000 tons in piles which are being constantly drawn upon.

The Iroquois Iron Company¶ of South Chicago keeps about 1,000 tons of run of mine coal from Christian County, Illinois, in storage for about eight months. The coal is stored within two or three weeks after being mined and the slack is removed before storing. It is placed on the ground in a continuous pile twenty-five feet high by means of a locomotive crane at an expense of ten cents per ton for storing and reclaiming. The coal is used for steam purposes and it does not

* H. D. DeHoll, Superintendent of the By-Product Coke Ovens.

† D. R. Mathias, General Superintendent.

‡ W. P. Gleason, General Superintendent.

¶ Perrin Rule, Superintendent.

depreciate materially in heating value, but suffers a loss of five per cent in breakage.

The Coal Products Manufacturing Company* of Joliet, Illinois, stores about 5,000 tons of run of mine from the Elkhorn and Logan Coal Company, West Virginia, and 3,000 tons of run of mine from Franklin and Williamson counties, Illinois, for a period of from 60 days to 90 days. The coal is stored, within a week or two after mining, on the ground in separate piles, thirty feet high by means of a bridge which is also used for reclaiming. The coal is used for the manufacture of by-product coke and no decrease in heating value has been noted. The Pocahontas coal heats within sixty days, but the Logan County coal has not done so. Heating is said to impair its coking qualities.

The Jones and Laughlin Steel Company† of Woodlawn, Pennsylvania, keeps in storage 100,000 tons of raw Pennsylvania No. 5 coal all of which is passed through a three-inch crusher, also 200,000 tons of washed Pennsylvania No. 5 which is passed through a $\frac{3}{4}$ -inch crusher. The coal is stored in pyramidal piles 300 feet wide and 350 feet long by means of a bridge and conveyor and is reclaimed by buckets from the bridge. The coal is stocked within three days after being mined and most of the washed coal is kept separate and left in storage for a period varying from four to eighteen months. The washed coal is stored at any time during the year, and the raw coal in November and December because of river navigation. The raw coal will fire spontaneously after about four months, starting about eight feet from the bottom of the pile, but while the washed coal heats up it does not fire. The raw coal is now piled only twenty feet deep instead of forty-five feet as formerly, and the washed coal is stored to a depth of forty-five feet.

Horace C. Porter of the H. Koppers Company of Pittsburgh says: "We have noted especially in the plant of the Lehigh Coke Company, South Bethlehem, Pennsylvania, now owned by the Bethlehem Steel Company the fact that the weathering of coal in the open has a considerable effect on its coking qualities after a certain period and affecting the degree of shrinking or of expanding of the coal during coking."

G. F. Downs, Superintendent of the Lackawanna Steel Company, Buffalo, New York, says:

"Our experience in stocking coal has been that any low sulphur coal, such as Pocahontas coal, can be piled to a height of thirty to sixty feet and will stand indefinitely without heating or firing.

"It is our experience that coals containing one per cent of sulphur and more cannot be piled higher than twelve to fifteen feet without heating and firing inside two months. We have tried piling such coals twenty to thirty feet high and using ventilating pipes, well distributed over the surface of the pile, but this gave no relief from the heating and we believe made the fire more rapid after it had once started as the pipes acted as flues."

The Calumet and Hecla Mining Company,‡ Calumet, Michigan, stored a max-

* A. H. Harris, Superintendent.

† A. W. Belden, Superintendent, Coke Department.

‡ James McNaughton, Vice-President and General Manager.

imum of 500,000 tons of coal from Thacker, West Virginia, and Mansfield, Pennsylvania, for a period of eight months, the coal being received within about two weeks after being mined and during the open navigation season from May to November. There is some depreciation in heating value but no material loss from breakage. If screened, there is no trouble from heating. The coal is stored both in sheds and in the open in continuous rectangular piles about twenty-five feet high. A tower system of storage is now being installed. About ten per cent of the coal is below three-fourths inches. Sizes are not kept separate in storage, but slack is removed. The expense of unloading from boats and storing is 15 cents per ton and the total reclaiming expense is $7\frac{1}{2}$ cents per ton in summer and $11\frac{1}{4}$ in winter. These amounts do not include rent, interest, or depreciation.

46. *Mine Storage.*—The simplest method of storage at the mine is by means of bins which form a part of the tipple structure or are located in a detached shed or building. Such bins provide a small storage capacity which will tide over any short stoppage of the mine and at mines where there are coke ovens and where it is necessary to insure a steady supply of oven coal they are extensively used. In the Pocahontas region of West Virginia, bins were at first built to take care of the slack only, but the system has gradually been extended to include all commercial sizes. In the Connellsville district of Pennsylvania the storage bins hold usually from 1000 to 2000 tons and permit the mines to be idle for a period of one day without interfering with the operation of the ovens. At some of the mines of the Middle West, particularly where coal is rescreened or washed, similar bins are used, but they are generally placed in a separate rescreening structure. The capacity of bins varies from 30 to 250 tons each and while they furnish small temporary storage for the washing or rescreening, they do not materially effect the operation of the large modern mines.

The Federal Coal Company of Straight Creek, Kentucky, recently built at the Barker mine a storage bin which holds 150 tons of run of mine coal. The purpose of this bin is to furnish storage for at least a part of a day's run in case cars are not placed at the mine, or in case there are not enough cars for the day's supply. With regard to this bin R. R. Atkins, Superintendent, says:

"We selected for the site for the storage bin, an old slate dump which was near our tipple and when dumping into the bin cars are shoved up a short grade to the top of this dump, about 15 feet above the dump at the tipple, and straight run of mine is placed in the bins, which have a gate at the bottom for discharging into railroad gondolas. This has proved to be so successful that we have plans under consideration for erecting bins at our other mines to be used in a similar way, but we do not contemplate the storage of coal in any quantities. It is our idea to build bins of such capacity that the size of the bin, together with the mine cars at each mine, will hold about a day's run. We believe that by doing this, we will be able to run our mines when we have no cars and also to load out a greater number of cars on days when the railroad places them, thus increasing our car allotment.

"While it is rather difficult for us to figure on the exact price of dumping the coal in this bin, and discharging it, we figure that the additional cost

amounts to about ten cents per ton. This could be considerably lowered by the erection of a bin of a different type but this would necessitate a greater expenditure of money in the erection of a bin as this bin was an experiment, we did not at the time feel justified in going to too heavy an expense."

Detailed descriptions of two plants for storing coal at the mines in Franklin County, Illinois, are given on pages 51 and 71, and for the large plant of the Clinchfield Fuel Company on page 64.

The Bell and Zoller Company at Zeigler, Franklin County, Illinois, during the winter of 1916-17 stored 45,000 to 50,000 tons of Nos. 3, 4, and 5 coal by means of a 1½-ton clam-shell bucket operated by a locomotive crane. The coal piles were from forty to fifty feet long and thirty feet high, and the three sizes were kept separate. No difficulty was experienced from firing, although the coal was kept in storage until the following winter. This coal was stored for the purchaser who paid the actual cost which was found to be slightly over three cents for unloading and from seven to eight cents for loading.

At the Security and Majestic mines in southern Illinois, coal has been stored on the ground for the Illinois Central Railroad by means of side dump cars furnished by the road. Whenever the coal companies had no cars for regular shipments, these cars were loaded and dumped on the ground near the tippie. The coal was reclaimed when needed with locomotive cranes.

Coal has been similarly stored at Buckner and Christopher, Illinois, by the Old Ben Mining Company. At one mine in central Illinois coal was stored in a small pond near the tippie and reclaimed with a locomotive crane.

In the report of the International Railway Fuel Association for 1915* occur the following suggestions for storage at the mines:

"At strip pit mines practical storage could be accomplished by leaving a small covering on the coal. If areas operated were large, from 50,000 to 100,000 tons could be partially uncovered in the summer and thus carried in storage without using the water covering method, and this, I believe, could be done at only small additional cost to reimburse the steam shovel operator for returning and uncovering and loading coal when season requires. A strip pit could be made to double or treble its daily production with only the one loading cost, and this would also reduce breakage."

This suggestion applies to coal which weathers very quickly, but for coal which stands the weather for a reasonable period of time a considerable storage capacity may be made available at stripping mines by taking off the surface and leaving the coal until it is needed; in fact, it is one of the advantages claimed for strip mining.

A. H. Davies,† Fuel Inspector of the Grand Trunk Pacific Railway, Pocatonton, Alberta, Canada, suggests the following system of storage for a mine in a hilly country (see Fig. 60):

"In mountainous districts, where seams are pitching, operators always enter the hillside at a point that gives them elevation for their tippie above the railroad track, generally about 25 to 30 feet.

* Proceedings, Vol. VII, p. 265.

† Ibid, pp. 273-275.

“At this depth, at foot of sloping hill, adjacent to tippie, a side-cutting about eight feet deep, and as long as capacity requires, at one per cent grade, dipping away from tippie, should be made. In this cutting construct tunnels of ordinary heavy timber, boxed in with round lugging or planking. Then bring rock dump at tippie level; parallel with tunnel and opposite the hill. The apex of rock dump to be 50 feet from center of tunnel-timber-collar, thus forming a V-shaped bin above tunnel. Trim or shear side of rock dump

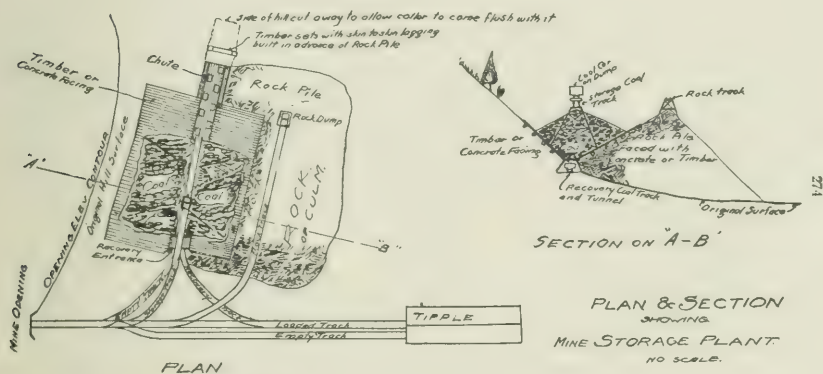


FIG. 60. SUGGESTED SYSTEM OF STORAGE FOR A MINE IN A HILLY COUNTRY
(Reproduced from the Proceedings of the International Railway Fuel Association)

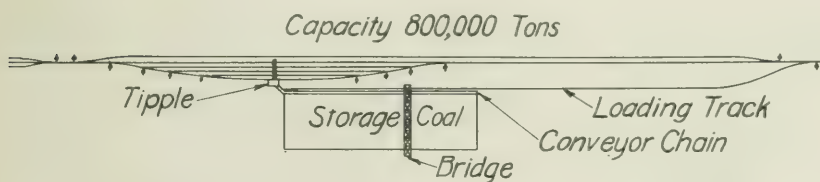


FIG. 61. SUGGESTED SYSTEM OF STORAGE FOR SCREENINGS AT THE TIPPIE
(Reproduced from the Proceedings of the International Railway Fuel Association)

and hillside to an angle of not less than 30 degrees. Cover over with layer of ashes, then corduroy, plank, or face with concrete, as desired. Construct double track on to storage bin on tippie elevation, one for loads and one for empties. From commencement of bin onwards, over and above whole length of bin, construct single track. To run on this track, build a detachable traveling carriage dump With 25 feet elevation from track in tunnel to track on tippie, the capacity would be approximately 2,000 tons per one hundred lineal feet of bin. If mine situated on level ground, prairie,

elevation is still available in tippie. The only difference would be, that another rock pile would have to be constructed, to replace natural hillside.''

Fig. 61 shows a plan suggested for storing screenings at the tippie.* The coal is carried from the tippie by a chain bucket conveyor which runs parallel with one side of the storage yard, the conveyor being supported on concrete posts, and provided with doors every ten feet through which the coal may be dropped to the ground, when the bridge bucket places the coal directly in the car standing on the loading track independent of the other mine tracks. Such a plan would cost more and seems to offer few advantages over the locomotive crane storage plant.

The Consolidation Coal Company†, Fairmont, West Virginia, stores coal in its mines in the Miller's Creek district of eastern Kentucky. The coal is stored during the summer time to supply the winter demand and is placed on the ground in long, narrow piles about thirty feet high. It is reclaimed by shoveling into mine cars. No heating has occurred but the amount of slack increases from thirty to fifty per cent. The coal contains about fifty per cent below three-fourths inches when stocked.

47. *Storage by Railroads.*—The subject of railroad storage has been discussed so fully by the International Railway Fuel Association since 1914 that it is very difficult to present any data not already contained in the Proceedings of the Association.

The replies to the questionnaire have brought out the following points:

The practice of the Illinois Central Railroad‡ may be summarized as follows:

The place where coal is to be stored should be free from all rubbish and special attention should be paid to drainage to avoid trouble from excessive moisture. The coal in storage should not be in contact with steam pipes.

It is advisable not to store the coal to a depth exceeding sixteen or eighteen feet, nor to a width exceeding thirty feet. Alleyways are left between the storage piles, thus separating the coal in storage into piles about thirty feet long.

After the storage piles have been completed, pipes, preferably old flues removed from locomotives, are placed at intervals, and staggered about the piles. In inserting the pipe into the coal pile a pointed wooded plug is placed in the end of the flue, so that it may be driven to the required depth without excessive labor. The flue should be driven through the coal to within about twenty-four to thirty inches of the soil and it should then be withdrawn sufficiently to permit the plug to be driven out of the pipe. By inserting a $\frac{7}{8}$ -inch rod through the top flue and using a medium hammer the wooden plug can be driven out through the bottom, thus creating an air chamber at the bottom of the flue in which temperature reading may be taken by means of a thermometer fastened to a line. Note of the atmospheric temperature should be made before inserting the thermometer into the flue. The thermometer should remain in the hole fifteen or twenty minutes. If the temperature of the pile is thirty degrees

* Ibid, Vol. VI, p. 124, 1914.

† Frank Haas, Consulting Engineer.

‡ H. B. Brown, General Fuel Inspector.

above that of the atmosphere, that part is immediately taken out and used. Since a rapid increase in temperature indicates excessive heat, arrange to remove the coal by the use of a locomotive crane or similar mechanical device.

Do not place fine coal on the bottom of the pile, and keep the bottom dry. Mixed screenings will fire more readily than unmixed.

The alleyways or spaces between the piles give an opportunity to save the coal with little expense and provide an easy means of locating trouble from heating.

Deterioration of coal in storage may be greatly reduced by a covering of small coal an inch or less in size.

Do not mix coals from different mines if it can be avoided, particularly when the action of a given coal in storage has been determined. Screenings particularly should not be mixed before storing. Instances are cited of screenings intended for power plant use which fired in the ear within a short time after having been rained on. Locomotive coal from the same mining region which had been stored twenty-five years had not fired.

The following instructions regarding storage of coal on the Rock Island Railroad were issued during the spring of 1917 by Carl Scholz, then manager of the mining and fuel department, in connection with the contemplated storage of 465,000 tons of coal at various points, 165,000 tons were to be used to effect car economies and to be reloaded after the peak-load of railroad transportation, and the remainder to insure an ample supply in case of labor trouble.

Instructions Governing Storage of Coal

“Engine coal is stored for the purpose of providing fuel at a time when the demand for it is greater than the current orders can provide or guard against shortage in case of suspension at the mines.

“In unloading coal, the reloading cost must always be considered, and the place selected for storing should be convenient to fuel chutes so as to handle coal with the minimum mileage from the storage pile to the place of ultimate consumption.

“In selecting the ground for storage pile, drainings should be fully considered, because the coal should not be stored on wet ground or filled material liable to cause spontaneous combustion. Hard clay is preferable as a foundation, with drainage on both sides, and if necessary, drainage tiles or ditches through the center.

“The 2-inch track unit has been accepted as standard. Under this arrangement, two tracks will be built at sixty-five foot centers. These tracks will be raised as the coal is unloaded, so as to rest on the storage pile itself until the piles reach their height limit. Then they will be removed and laid at fifteen-foot centers between the piles, thereby enabling the reloading of coal, either by hand or clam-shell, the clam-shell to travel on one track and the cars to be loaded to occupy the other track.

“Where Illinois and Iowa coals are stored, the coal piles should not exceed a maximum height of fifteen feet, but with Oklahoma coal the height may go to twenty or twenty-two feet.

“A unit built of this plan of forty cars lengths will store approximately

35,000 tons of coal. As far as possible, drop bottom cars will be furnished for the handling of storage coal.

"Immediately after heavy rains, it is desirable not to pile fresh coal on the stored coal until the moisture has had a chance to evaporate. Care should be taken to reject cars containing an unusual amount of slack, and such cars should be switched and sent to fuel chutes for immediate consumption, so that coarse coal is stored as far as possible.

"The reloading track which remains on the ground should not be covered more than three or four feet above the rails. For the purpose of observing any rising temperature, flues or old pipes should be driven in the storage pile every 300 feet so that a thermometer can be suspended therein to note any rise in temperature."

The Central of Georgia Railway* stores 31,500 tons of Alabama coal four inches and under in size, without separating it into sizes or taking out the fine coal, about five days after it is mined and keeps it in storage six months. To insure a regular supply and for winter use, coal is stored in July, August, and September, because the railroad business is dull and necessary equipment is available for storage; also the price of coal is usually lower.

It is placed on the ground in continuous, long, narrow piles limited to fifteen feet in height and is reclaimed with a locomotive crane at an expense of 2.58 cents per ton for storing, and 2.09 cents per ton for reclaiming, including labor and supplies. Rental of tracks, depreciation, interest, and insurance are not included in these amounts. Coal is thought to decrease in heating value not more than five per cent. There was no loss from breakage and no heating. Sixty thousand tons stored for six months burned very well.

The Louisville & Nashville Railroad† has forty-six coaling stations and at some of them coal is stored in amounts varying from 50 to 25,000 tons on the ground or more generally on a timber floor. It is placed in small bins by hand or in large bins by gravity from a trestle or by a locomotive crane from cars. A circular system is also used. It is reclaimed by locomotive crane or by hand.

The height of the pile depends upon the coal used, being limited in some cases to twelve feet and in others reaching to more than twenty feet without heating. In case of heating, the coal is removed or sprinkled with water. Coal is kept in storage indefinitely and is stored during the summer to take advantage of the low price, to relieve car service in winter, and to insure supply. Sizes are not kept separate and fine coal is not removed. The heating value is thought to decrease and the extent to which coal will heat depends upon the height of the pile and the condition of the coal when received.

The Baltimore & Ohio Railroad‡ is using industrial tracks, which are elevated or are raised on cribs, to store on the ground run of mine coal from Somerset, Pennsylvania. In this way cars are released promptly. The coal is reclaimed with a locomotive crane and there is only a slight loss in heating value and a slight breakage loss.

* A. P. Wells, Engineer of Tests.

† Engineering Record, 1914-15, Engineering News, 1914-15.

‡ W. H. Averell, General Manager.

The Chicago & Northwestern Railroad* stores from 12,000 to 40,000 tons of coal from Macoupin County, Illinois, generally storing the six-inch lump, and using the fine coal at once. Run of mine has also been stored. Continuous piles not over twelve feet high are used with tubes placed for temperature observations and the piles are very closely watched. This method has been tried for four years and if deterioration occurs it is mostly during the first few months and not after one year.

The Southern Railway System† stores about 10,000 tons of Illinois and Kentucky screened coal at Danville, Kentucky, 18,000 tons at Huntington, Indiana, and also from 60,000 to 180,000 tons of coals from Middlesboro, Kentucky, and southwest Virginia. These are stored within two to twenty days after being mined and are kept in storage from four to eight months. The coal is stored on the ground in continuous piles from ten to fourteen feet high. The slack is not removed and the sizes are not kept separate. There is thought to be a ten per cent decrease in heating value and a breakage loss of fifteen per cent. The coal sometimes heats but it has never fired. The piles are limited to a height of fourteen feet. If heating occurs, the coal is picked up and used immediately, or is spread out and allowed to cool. Goodwin says: "Theoretically, there is little decrease in heating value, but practically, on account of the slack present, we do not get the same results from stored coal as from fresh."

The Michigan Central Railroad‡ had in storage at Gary, Indiana, during the summer of 1917, 35,000 tons of 1¼-inch lump and run of mine coal from West Clinton, Indiana, and from Harrisburg and Freeburg, Illinois. The sizes were not kept separate and the slack was not removed. The coal was stored from five to fifteen days after being mined. It was placed on the ground by hand or by clam-shell buckets in long piles eighteen feet deep. This coal had been in storage for four or five months when it took fire, although at other times coal had been kept from eight to eighteen months without firing. Where the fire started, the pile was not more than twelve feet high. At the point of firing there was found to be a quantity of very dry fine slack. The moisture had evidently been dried out by the heat from below, since the coal above this spot was damp and this dampness evidently came from the moisture being driven from the coal below. Where the coal fired it was lumpy or coarse, and covered with very fine slack. Apparently the slack retained the heat and did not permit it to radiate, so that the temperature gradually rose to the ignition point. After the fires had been dug out the remaining coal cooled and since then no fires or extreme heat have been noticed.

The Chicago, Lake Shore & South Bend Railroad¶ stores about 3,000 tons of coal from Clinton, Indiana, on the ground in continuous piles about fourteen feet high. The sizes are kept separate in storage and slack is removed. The coal is stored two weeks after being mined and, if possible, is placed in storage between the first of September and the first of December because of the prevailing favorable

*W. E. Dunham, Supervisor of Motive Power.

† C. G. Goodwin, Fuel Agent.

‡ J. C. Dougherty, Coal Inspector.

¶ W. E. Bolston, Superintendent of Power and Equipment.

weather conditions during that period. It is kept in storage about one year. There is a slight decrease in heating value and heating is likely to occur in from one to six months. In case of heating, the coal is removed at once. To avoid heating, the piles are kept small and low in height. The coal is handled by means of a locomotive crane at a cost of twelve cents per ton for storing and reclaiming.

Chicago, Burlington & Quincy Railroad* had in storage October 1, 1917, 562,000 tons of coal, which were stored between April and September. This coal was intended for use in November and December. The experience of the Burlington as given by Crawford is summarized as follows:

At Havelock, Nebraska, there were stored 8,000 tons of coal from the Virden, Illinois, district in long piles from twelve to fifteen feet high and forty-two feet wide. The coal was stored early in June and about July 30 was reported to be heating throughout. Although the company began to load out the coal at once, heating continued to spread rapidly and on August 16 a pipe was laid to the pile which was spread out so that the coal was only from three to five feet thick and water was put on it day and night; consequently it is stated that only five per cent of the coal was lost. In other piles at Galesburg and Savanna, Illinois, there was similar trouble from firing.

At Clyde, Illinois, southern Illinois screenings were stored and where fires occurred, Crawford attributes them to excessive depth of piles. The general policy of the Burlington is to store from April to September, and where two coals from different districts are stored at the same point, to keep the different coals in separate piles. Egg and lump coals are not separated, but where the storage coal is to be handled with a clam-shell directly upon an engine, it is advisable to store only egg coal. Coal should be stored in as dry weather as possible. Superintendents are advised to store coal on ground reasonably level and as high as possible from which rubbish has been removed, and not over steam lines.

Crawford states:

"I think every one should figure that there is going to be heating in storage coal and should provide full means for dissipating that heat. The only way I know of to stop this heating in coal storage is to store the coal low enough, and be careful to store lump and egg coals so that there will be reasonably free circulation.

"It is impracticable for a railroad to allow coal to season in a car, and a better way to let it season is to store it in long piles, building it up gradually. Here, however, we come to the point of the advisability of putting freshly mined coal upon a pile of coal already stored which has been subjected to the rays of the sun when the temperature is around 100 degrees. In other words, I think the fresh coal will pick up more heat from a pile of storage coal than it would from the ground.

"I am satisfied that by carefully inspecting the Belleville district coal going into the North St. Louis pile which is seventeen feet high that we saved a fire at this point. The mines started to ship us mine run billed lump and fortunately we discovered this in time and placed an inspector in the district."

* J. G. Crawford, Fuel Engineer.

The Missouri, Kansas & Texas Railroad* stores Illinois 2-inch lump coal from the Belleville district, coal from the Pittsburgh district, Kansas, with twenty-five per cent of the slack removed, called modified lump, mine run coal from the McAlester district, Oklahoma, and also coal from Thurber, Texas. The coal is kept in storage from six months to one year. Different varieties and different sizes are piled separately. It has been found, that coal from the McAlester district, Oklahoma, will fire when mixed with coal from the Lehigh district, Oklahoma. The slack is removed except where Oklahoma mine run is stored. As much time as possible is recommended between the mining and storing, and March, April, May, and September are considered the best months in which to store. There is thought to be a slight loss in heating value and a slight breakage loss. Hibben summarizes his practice as follows:

“Heating depends upon the manner in which the coal is stored and the kinds of coal. It is not wise to store fine coal and lump should be used, if possible. Do not pile over fifteen feet high. The cost of storing with clam-shell buckets has been 3½ cents per ton which includes the cost of construction of new track when necessary, the salary of the operator and other necessary employees to remove the coal left in the car. The estimated cost for reclaiming is the same.”

C. M. Butler, of the Atlantic Coast Line, said at the 1917 meeting of the Railway Fuel Association:

“There will be a week or ten days when from certain coal supplies we do not receive a single car. That is not due to the fact that the mines have not been shipping it, but it is due to the fact that railroad companies handling the coal from the mines to us have been unable to get it to us. Then there is another week when we will get three times as much coal as we need. The result is that we have a surplus of coal loaded in cars, and in order to help the situation we have made some arrangements to release that coal regardless of consumption. We have made places all over our line to store coal, and to store coal this week and use it next and restore it in the same place and pick it up, simply to release the cars. I feel sure that our own little supply has been very much helped by our prompt handling of the cars; not only from the fact that we have put those cars back to the mines to be reloaded, but we have created a feeling at the mines where our coal is loaded that any coal allotted to us will receive prompt attention and the cars will not be held indefinitely.”

The Atlantic Coast Line keeps Virginia and West Virginia run of mine, high volatile coals in storage for six months without separating the sizes and without removing the slack, there being from fifty to sixty per cent slack below ¾ inches in the coal when stored. Some of the piles are continuous and some are partitioned into sections. The coal is stored in August and September, before the heavy fall traffic, and is placed in semicircular piles, twenty-five feet high, by means of a locomotive crane which takes the coal from a pit. If stored in a wet place or in a high pile, the coal heats very soon after being stored. The expenditure

* R. R. Hibben, Assistant Fuel Agent.

for labor, operation, repairs, and maintenance varies from four to five cents per ton, depending upon the appliances used.

The Grand Trunk Pacific Railroad* stored 150,000 tons of Ohio and Pittsburgh No. 8 coal over $\frac{3}{4}$ inches in size and 40,000 tons of Jasper Park Alberta mine run coal containing 70 per cent below $\frac{3}{4}$ inches on the ground in continuous piles twenty-four feet high by laying a track on top of the pile as it is gradually built up. It is reclaimed by hand, by a clam-shell bucket, and occasionally also by a ditcher. It is stored during the dry months when the coal is available and usually about three weeks after mining. It has been in storage from one to five years with little firing, no appreciable deterioration in heating value, and little degradation, but this is stored in a cold climate. The expenditure for labor and supplies is eight cents per ton for stocking, and 6.2 cents for reclaiming.

The accompanying illustrations (Figs. 62 and 63) show a coal pile stored by the C. C. C. & St. L. R. R., near Hillary, Illinois, west of Danville. About 30,000 tons of run of mine, No. 7 coal were stored, in from one to three days after being mined, in two piles and to a depth of from fifteen to twenty feet by means of tracks on top of the piles. (See also Figs. 6 and 7 on page 45). No attempt was made to remove the fine coal. Most of the fine coal fell on the north side of the pile and the lump on the south side. In the east pile pipes were placed and temperature readings taken daily at points, 5, 10, 15, and 20 feet from the top. The log of these readings as given by P. T. White, Superintendent of the C. C. C. & St. L. R. R., is presented as Table 7. A temperature of 170 degrees was recorded shortly before the fire broke out in the pile, the highest temperature being recorded usually five feet below the top of the pile. Fire broke out after several days of intensely hot weather, which were followed by heavy thunder storm and then by more days of hot humid weather. The starting of the fire in the west pile is shown in Fig. 62 and the same fire a few days afterwards is shown in Fig. 63.

The appearance of the pile at one point after the burning coal had been loaded out is shown in Fig. 63, which shows that there was a large amount of very fine coal. As the hot and steaming coal was loaded out, it was quenched with water and used immediately. P. T. White, Superintendent of the Big Four, says:

“One place where the storage pile was burning we smothered with dirt and two days later on opening this place up with the steam shovel, we found the coal at an intense white heat, fire extending for about six feet into the pile. I am inclined to believe that our trouble this year is due to the great quantities of impurities and slack in the coal and to the peculiar weather conditions that prevailed just previous to the fire. I am of the opinion that successful storing of coal demands that coal be reasonably free from impurities and slack.”

The C. C. C. & St. L. R. R. also had fire in coal at Beech Grove, Springfield, and Bellefontaine, Ohio, and Mattoon, Illinois, stored similarly to that at Hillary.

* T. Duff Smith, Fuel Agent.



FIG. 62. COAL PILE OF THE C. C. C. AND ST. L. R. R. NEAR HILLARY, ILLINOIS
THIS PILE CONTAINED ABOUT 30,000 TONS OF NO. 7 RUN OF MINE COAL
WHICH FIRED IN THE SUMMER OF 1917



FIG. 63. ANOTHER VIEW OF THE BURNING COAL PILE OF THE C. C. C. AND ST. L.
R. R. NEAR HILLARY, ILLINOIS, IN THE SUMMER OF 1917

TABLE 7
TEMPERATURE OF COAL STORED AT HILLARY, ILLINOIS, BY THE C. C. C. & ST. L. R. R.

Pipe No. 1				Pipe No. 2				Pipe No. 3				Pipe No. 4				
Date	5 ft.	10 ft.	15 ft.	20 ft.	5 ft.	10 ft.	15 ft.	20 ft.	5 ft.	10 ft.	15 ft.	20 ft.	5 ft.	10 ft.	15 ft.	20 ft.
7-13	150°	152°	150°	110°	116°	108°	100°	94°	150°	126°	90°	84°	120°	110°	88°	74°
7-14	150	160	140	100	110	108	98	92	126	120	108	102	120	110	96	90
7-15	154	150	120	112	102	106	96	88	116	106	90	84	120	114	102	96
7-16	148	154	130	122	120	112	84	80	130	122	92	80	128	110	92	84
7-17	152	162	134	94	120	114	102	86	126	126	112	96	118	114	94	86
7-18	146	158	130	132	114	112	98	86	112	114	104	96	110	102	94	82
7-19	154	162	132	102	124	118	106	94	132	124	108	86	120	114	96	84
7-21	150	156	106	94	130	116	102	90	134	112	100	92	116	106	90	84
7-23	154	142	114	98	130	116	106	90	134	112	100	92	116	106	90	84
7-25	154	140	122	102	128	118	104	88	134	112	100	92	116	106	90	84
7-26	162	150	124	94	130	112	94	90	132	112	104	90	120	110	94	86
7-28	160	144	120	108	124	108	100	94	126	114	104	92	128	112	98	86
7-29	146	138	118	92	118	106	94	86	120	108	98	88	126	110	96	84
7-30	154	146	118	102	126	114	102	84	140	116	104	88	112	106	94	84
7-31	166	148	116	98	130	110	94	88	130	112	92	80	128	120	102	84
8-1	152	144	128	106	112	112	98	82	134	110	102	80	124	108	92	86
8-2	164	146	124	90	112	114	94	86	116	108	98	88	122	110	102	86
8-3	156	148	122	94	128	114	94	82	134	110	96	80	120	108	92	86
8-4	158	148	114	96	112	108	106	76	114	112	102	82	126	112	96	88
8-5	170	154	128	88	132	112	106	92	122	110	102	84	124	106	94	86
8-6	162	148	126	104	126	112	106	92	134	120	102	84	124	106	94	86
8-7	164	148	128	106	118	104	96	94	144	132	110	82	134	118	106	82
8-8	162	160	136	114	118	104	96	94	144	132	110	82	130	122	108	82
8-9	164	156	132	112	124	108	102	94	144	132	110	82	130	122	108	82
8-10	154	152	140	118	122	120	112	98	128	122	106	102	122	110	96	88

¹ West pile fired.
 East pile fired August 14.
 Note:—No temperature taken between July 19 and 24, on account of thermometer being broken.

LIST OF PUBLICATIONS OF THE ENGINEERING EXPERIMENT STATION

- Bulletin No. 1.* Tests of Reinforced Concrete Beams, by Arthur N. Talbot. 1904. *None available.*
- Circular No. 1.* High-Speed Tool Steels, by L. P. Breckenridge. 1905. *None available.*
- Bulletin No. 2.* Tests of High-Speed Tool Steels on Cast Iron, by L. P. Breckenridge and Henry B. Dirks. 1905. *None available.*
- Circular No. 2.* Drainage of Earth Roads, by Ira O. Baker. 1906. *None available.*
- Circular No. 3.* Fuel Tests with Illinois Coal (Compiled from tests made by the Technological Branch of the U. S. G. S., at the St. Louis, Mo., Fuel Testing Plant, 1904-1907), by L. P. Breckenridge and Paul Diserens. 1908. *Thirty cents.*
- Bulletin No. 3.* The Engineering Experiment Station of the University of Illinois, by L. P. Breckenridge. 1906. *None available.*
- Bulletin No. 4.* Tests of Reinforced Concrete Beams, Series of 1905, by Arthur N. Talbot 1906. *Forty-five cents.*
- Bulletin No. 5.* Resistance of Tubes to Collapse, by Albert P. Carman and M. L. Carr. 1906. *None available.*
- Bulletin No. 6.* Holding Power of Railroad Spikes, by Roy I. Webber. 1906. *None available.*
- Bulletin No. 7.* Fuel Tests with Illinois Coals, by L. P. Breckenridge, S. W. Parr, and Henry B. Dirks. 1906. *None available.*
- Bulletin No. 8.* Tests of Concrete: I, Shear; II, Bond, by Arthur N. Talbot. 1906. *None available.*
- Bulletin No. 9.* An Extension of the Dewey Decimal System of Classification Applied to the Engineering Industries, by L. P. Breckenridge and G. A. Goodenough. 1906. Revised Edition 1912. *Fifty cents.*
- Bulletin No. 10.* Tests of Concrete and Reinforced Concrete Columns, Series of 1906, by Arthur N. Talbot. 1907. *None available.*
- Bulletin No. 11.* The Effect of Scale on the Transmission of Heat through Locomotive Boiler Tubes, by Edward C. Schmidt and John M. Snodgrass. 1907. *None available.*
- Bulletin No. 12.* Tests of Reinforced Concrete T-Beams, Series of 1906, by Arthur N. Talbot. 1907. *None available.*
- Bulletin No. 13.* An Extension of the Dewey Decimal System of Classification Applied to Architecture and Building, by N. Clifford Ricker. 1907. *None available.*
- Bulletin No. 14.* Tests of Reinforced Concrete Beams, Series of 1906, by Arthur N. Talbot. 1907. *None available.*
- Bulletin No. 15.* How to Burn Illinois Coal Without Smoke, by L. P. Breckenridge. 1908. *None available.*
- Bulletin No. 16.* A Study of Roof Trusses, by N. Clifford Ricker. 1908. *None available.*
- Bulletin No. 17.* The Weathering of Coal, by S. W. Parr, N. D. Hamilton, and W. F. Wheeler. 1908. *None available.*
- Bulletin No. 18.* The Strength of Chain Links, by G. A. Goodenough and L. E. Moore. 1908. *Forty cents.*
- Bulletin No. 19.* Comparative Tests of Carbon, Metallized Carbon and Tantalum Filament Lamps, by T. H. Amrine. 1908. *None available.*
- Bulletin No. 20.* Tests of Concrete and Reinforced Concrete Columns, Series of 1907, by Arthur N. Talbot. 1908. *None available.*
- Bulletin No. 21.* Tests of a Liquid Air Plant, by C. S. Hudson and C. M. Garland. 1908. *Fifteen cents.*
- Bulletin No. 22.* Tests of Cast-Iron and Reinforced Concrete Culvert Pipe, by Arthur N. Talbot. 1908. *None available.*
- Bulletin No. 23.* Voids, Settlement and Weight of Crushed Stone, by Ira O. Baker. 1908. *Fifteen cents.*
- *Bulletin No. 24.* The Modification of Illinois Coal by Low Temperature Distillation, by S. W. Parr and C. K. Francis. 1908. *Thirty cents.*
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